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Identification of Eco-efficient Improvement Opportunities in the Industrial Networks of Small and Medium-sized Enterprises

By Dick van Beers

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University of Cape Town
Department of Chemical Engineering
Environmental Process Engineering Group
Rondebosch
South Africa

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Student: Dick van Beers
BSc. (Hons.) Industrial Engineering
13 Nangostreet (private address)
Sanddrift East
7441 Milnerton
South Africa
Tel. (++27) (0)21 650 40 35
Fax (++27) (0)21 689 75 79
E-mail: dick@chemeng.uct.ac.za

Research Institute: University of Cape Town
Department of Chemical Engineering
Environmental Process Engineering Group
Rondebosch 7700
Cape Town
South Africa
Tel. (++27) (0)21 650 40 35
Fax (++27) (0)21 689 75 79

Supervisors: Dr. Harro von Blottnitz
University of Cape Town
Department of Chemical Engineering
Environmental Process Engineering Group
Rondebosch 7700
Cape Town
South Africa
Tel. (++27) (0)21 650 25 12
Fax (++27) (0)21 689 75 79
E-mail: hvb@chemeng.uct.ac.za

A-Professor John Raimondo
Gibb Africa
PO Box 3965
8000
Cape Town
Tel. (++27) (0)21 469 92 26
Fax (++27) (0)21 424 67 09
E-mail: raimondo@iafrica.com

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Synopsis

The central problem on which this Masters research project builds is the perceived limited ability of small and medium-sized enterprises (SMEs) in the South African manufacturing sector to improve their environmental performance on their own.

Waste minimisation is a valid and proven tool for the identification of ways to reduce or eliminate wastes. However, the systems boundaries, scope, and focus of the WM-methodology seem be too narrow to achieve the required environmental improvement in the South African manufacturing sector; so that a broader approach might be necessary.

A methodology has been developed to improve the environmental and economic performance of an SME by changing the intensities, connections and contents of the material, financial and information flows between the SME and one or more of its network partners.

The proposed methodology is referred as the industrial network approach and aims to overcome the limitations of the WM-methodology. The industrial network approach consists of four phases; viz. the inventory phase, the assessment phase, the discussion / selection phase and the feasibility phase.

During the inventory phase, information on the structure and functioning of the company's industrial network is gathered, and the industrial network is visualised. Improvement options within the industrial network of the company are sought in the assessment phase. The identified improvement options have to be discussed and the options with the highest potential to be successful have to be selected. The last phase consists of a feasibility analysis on the selected improvement options.

One technique to identify potential network improvements is to conduct a network brainstorming session which is done with company staff of the SME. An industrial ecology checklist is used as a guideline during the discussion. This checklist is an abridged version of the checklists set up by Graedel & Allenby [1995] and DeSimone & Popoff [1997].

The second technique to generate potential network improvements is to conduct a network impact matrix. The network impact matrix is based on the matrix LCA as described by Graedel [1998]. The aim of the network impact matrix is the identification of environmental constraints within the industrial network. Once the network constraints have been identified, possible ways to eliminate these constraints can be sought through a pro-active partnership approach.

The developed industrial approach was tested on two SMEs, namely a textile printing company and powder coating company of aluminium products. The textile and the metal finishing sector were selected as these sectors have been identified as the 3rd and 4th most polluting industries in South Africa, and as sectors in which SMEs are well represented [EMG, 1993].

A full waste minimisation assessment had been conducted at the powder coating company before the industrial network assessment started. The textile printing company did not carry out a waste minimisation assessment. For the textile company, it was therefor not possible to compare the results of the industrial network approach with those from a waste minimisation assessment.

The total number of feasible improvement options in the industrial network of both case-study companies, as identified by the industrial network assessment, was regarded as low. The performance of the network impact matrix was considered to be poor, a network brainstorming session appeared to be a more appropriate tool to identify improvement opportunities within the industrial network of an SME.

The hypothesis for this research project was formulated as "Feasible eco-efficient improvement opportunities, which would not have been identified by a waste minimisation assessment, can be found within the industrial network of an SME". The application of the developed method revealed that the industrial network in which an SME operates naturally offers opportunities for the SME to improve its environmental performance. It can therefor be concluded that this formulated hypothesis is true. However, the developed methodology, as proposed in this thesis, is not an appropriate tool for SMEs to use instead of or in addition to a waste minimisation assessment. Rather, it is recommended that the strengths of the developed and described industrial network approach are incorporated into the existing WM-methodology.

The proposed modification of the existing WM-procedure is shown in Figure 1. Each modification is marked in bold. Additional research is necessarily to validate the recommended modifications of the WM-methodology.

Phase 1: Planning and organisation
- Get commitment from company management **and network partners, or at least inform network partners about project** - define scope and boundaries of the project - set up a project team, consisting of company employees and **network partners,** and define responsibilities - set up goals (quantitative or qualitative) and time-planning - identify sources of data and contact persons
Phase 2: Pre-assessment
- identify, characterise, and track the facilities of waste streams - draw up process flow charts - determine mass and energy flows - start making rough mass and energy balances - **identify, characterise network partners and its relationships with the company** - **map industrial network of company** - identify the main environmental costs - select main focus areas
Phase 3: Assessment
- compile background information on processes, waste types and sources, technologies, wm-practices and environmental impacts - gather additional data - close mass and energy balances - generate options (WM-checklists, **industrial network checklist,** literature, industry experts) - screen and select options for further study
Phase 4: Feasibility
- technical evaluation - economical evaluation - environmental evaluation - **social evaluation**
Phase 5: Implementation
- get commitment from company management and **network partners** - set up project team, consisting of company employees and **network partners**, for implementation of option - allocate tasks and responsibilities - determine costs and **profit sharing with network partners** - determine time-planning - implementation - evaluate performance

Figure 1 Proposed Modification of the Existing WM-methodology

By modifying the existing WM-methodology with the proposed suggestions, the scope of the WM-assessment is extended. Besides the identification of improvement options within the physical boundaries of the company, the modified WM-methodology would now also aim to identify improvements in the industrial network in which the company operates (external improvements). It would therefor be important to involve network partners of the company during the entire waste minimisation exercise.

Preface

Hereby I, Dick van Beers, declare that unless indicated, this Masters thesis is my own work and that it has not been submitted, in whole or in part, for a degree at another educational institute.

Dick van Beers,

signed on September 9, 2000

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List of Abbreviations

Abbreviation	*Description*
AAAMSA	Association of Architectural Aluminium South Africa
AFSA	Aluminium Federation South Africa
BOD	Biological Oxygen Demand
BUDS	Business Development Service
BS	British Standard
CADFA	South African Dyers and Finishers Association
COSATU	Congress of South African Trade Unions
CSIR	Council for Scientific and Industrial Research
CP	Cleaner Production
CSIR	Council Scientific Industrial Research
CWIU	Chemical Workers Industrial Union
DTI	Department of Trade and Industry
EMS	Environmental Management System
EPA	Environmental Protection Agency
EPCMA	Eastern Province Clothing Manufacturers Association
EU	European Union
GDP	Gross Domestic Product
IDC	Industrial Development Corporation
ISO	International Standard Organisation
IWM	Institute Waste Management
JIT	Just-In-Time
MIEU	Motor Industry Employees' Union
MISA	Motor Industry Staff Association
MITB	Motor Industry Training Board
MSDS	Material Safety Data Sheet
NAACAM	National Association of Automobile Component and Allied Manufacturers
NAAMSA	National Association of Automobile Manufacturers South Africa
NCMA	Natal Clothing Manufacturers Association
NGO	Non-Governmental Organisation
NUMSA	National Union of Metalworkers South Africa

LCA	Life Cycle Assessment
RSA	Republic of South Africa
SAAO	South African Automobile Association
SABS	South Africa Bureau of Standards
SACTPEA	South African Cotton Textile Processing Employers Organisation
SACTWU	South African Clothing and Textile Workers Union
SADFA	South African Dyers and Finishers Association
SAMIEA	South African Motor Industry Engineering Association
SEIFSA	Steel and Engineering Industries Federation of South Africa
SETAC	Society of Environmental Toxicology And Chemistry
SFA	Substance Flow Analysis
SIEFSA	Steel Iron Engineering Federation of South Africa
SSA	Statistics South Africa
SME	Small and Medium sized Enterprises
SMME	Small, Medium and Micro sized Enterprises
TCMA	Transvaal Clothing Manufacturers Association
TI	Textile Institute
TTB	Textile Training Board
UCT	University of Cape Town
UNEP	United Nations Environment Program
USEPA	United States Environmental Protection Agency
WBCSD	World Business Council for Sustainable Development
WMC	Waste Minimisation Club
WMIG	Waste Minimisation Interest Group
WRC	Water Research Commission

Glossary

Word	*Description*
Bleaching (textile processing)	Bleaching whitens fabric once impurities have been removed. The natural colouring matter is destroyed, using oxidising or reducing agents, leaving te material white.
Captive shop (metal finishing)	In-house operation performing metal finishing activities on the parts that they manufacture and/or they subsequently use in downstream manufacturing.
Chromate coating (metal finishing)	A corrosion protection technique which many variations and can be applied to steel, aluminium, magnesium and zinc. It results in the formation of metal oxide on the surface of the work-piece that reacts to form metallic chromates.
Conversion coating (metal finishing)	A coating produced by chemical or electro-chemical treatment of a metal surface that provides a superficial layer containing a compound of the metal.
De-sizing (textile processing)	De-sizing is commonly the first wet stage in the processing of cotton, and is the removal of size from fabric prior to further processing. De-sizing ensures that subsequent chemical finishing processes function correctly. Size removal is normally achieved using enzymes, oxidation, hot water rinsing, and emulsifiers.
Drag-out (metal finishing)	The solution that adheres to a work-piece removed from a bath that will be carried through the next bath (drag-in), and that may drip between baths.
Drying (textile processing)	Drying of fabric is closely associated with finishing processes and is required to prevent fabric distortion after wet processing. Hydroextraction removes excess water before drying, and should be as complete as possible to reduce costs.
Dyeing (textile processing)	Dyeing in its simplest form is the movement of dye from a solution onto fabric; the dye liquor gradually loses colour whilst the fabric becomes coloured. Water is required for all forms of dying, either as a solvent or transport medium and, therefore, effluent is generated by all dyeing processes.
Effluent	Any gas or liquid emerging from a pipe or similar outlet; usually refers to waste products from chemical or industrial plants as liquid mixtures or stack gases.
End-of-pipe	Treating pollutants at the end of a process, for example by filters, catalysts and scrubbers, instead of using preventing their occurrence.
Environmental management system (EMS)	A management system aiming at facilitating improved environmental performance that involves a complete review of the environmental effects produced by a company, the formulation of an environmental policy designed to ameliorate the identified effects and procedures to achieve the aims and objectives of the policy.
Environmental networking	Co-operation of businesses with the aim to achieve a better overall environmental performance than a firm could achieve individually (thesis definition).

Finishing (textile processing)	Finishing refers to any processes used to improve the quality of the fabric after dyeing, and is the last process prior to final inspection and delivery. Chemical processes include the coating of fabric with chemicals to improve fastness properties and appearance; while physical methods such as brushing can alter the handle (feel) of the fabric.
Industrial ecology	A concept in which an industrial system is viewed not isolation from its surrounding system but in concert with them [Jelinski, 1992]. Industrial ecology employs a holistic view to study, assess and improve the utilisation of natural resources (materials and energy) in an industrial society [van Berkel et al, 1995].
Industrial network	An industrial network is a web of organisations connected, directly or indirectly, by material, financial and information flow with different magnitudes (thesis definition).
Industrial network assessment	Methodology, as developed and described in this thesis, to identify eco-efficient improvements in the industrial networks of companies (also referred as the industrial network approach).
Job-shop (metal finishing)	Job-shop (independent) metal finishing operations do manufacture parts or use their products in other manufacturing applications. They are separate entities offering the service of metal finishing to other manufacturers and the public.
Life Cycle Assessment (LCA)	The process of evaluating the effects that a product has on the environment over the entire period of its life cycle.
Mercerising (textile processing)	Mercerising is a process used on cotton yarns and fabrics to improve sheen, strength and dye affinity. Whilst under tension, fabric is impregnated with cold concentrated sodium hydroxide solution.
Metal finishing	The process of coating a metallic (or plastic in the case of electroless plating) object with one or more layers of another metal, paint, plastic, or ceramic to enhance, alter, or finish its surface.
Network brainstorming session	A technique to identify potential improvement opportunities in an industrial network of a company. During the discussions a checklist is used as a guideline; the checklist is based on the work of Graedel & Allenby [1995] and DeSimone & Popoff [1997].
Network impact matrix	A technique, based on a matrix LCA, to generate potential improvement opportunities in an industrial network of a company.
Networking of businesses	Co-operation of companies in order to compete more effectively or to achieve together what each firm could not achieve alone [Lichtenstein and Hoeveler, 1996].
Pickling (metal finishing)	A chemical treatment which removes oxide or scale from the surface of a metal. It most often refers to the use of sulphuric or hydrochloric acid to remove scale formed on mild and low-ally steel.
Printing (textile processing)	Printing involves the coating of fabric with dye pastes in various colours and designs.

Rinsing (textile processing)	Rinsing uses large volumes of water to wash fabric, removing any dirt and impurities.
Scouring (textile processing)	Scouring removes impurities by destruction and solubilisation. Normal scouring materials are alkalis (e.g. sodium carbonate), and are frequently used in the presence of surfactants.
Sizing (textile processing)	Sizing is the coating of a yarn for protection from abrasive action of weaving looms, ensuring a smooth finish. Sizing products are organic compounds and fall into three groups: natural starches, modified starches, and synthetic polymers. The choice of size determined by the fibre and yarn type, application method, fabric construction and weaving efficiency.
Stakeholders	The broadest definition of "stakeholders" brings in anyone who affects or is affected by a company's operations. The key new perception is that companies need to expand the range of interests considered in any new development from customers, shareholders, management and employees to such people as suppliers, local communities and pressure groups [WBSD, no date].
Sub-system	A sub-system can be regarded as some process which transforms certain input flows of money, materials, energy, information or decisions into corresponding outputs [Jenkins, 1969].
System	a plan or a scheme according to which things are connected into a whole
Systems thinking / analysis	The aim of thinking or analysis is to provide a method by which complex problems, activities and organisations can be analysis {Jenkins, 1969].
Waste	All solid, liquid and gaseous materials introduced into the air, water and soil.
Waste minimisation	The reduction, to the extent feasible, of waste that is generated or subsequently treated, stored or disposed of. It includes any source reduction and recycling activity undertaken by a waste generator that result in either (i) the reduction of total volume or quantity of waste, or (ii) the reduction of toxicity of waste, or both, so long as such reduction is consistent with the goal of minimising present and future threats to human health and the environment [PMG, 1998]. (According to the NWMS for South Africa).
Waste minimisation assessment	A systematic planned procedure with the objective of identifying ways to reduce or eliminate waste (waste audit).

1 Introduction

1.1 Background

South Africa is a country in transition. The government seeks economic growth and social transformation. It has passed new legislation and is liberating trade. There is a strong need to improve both the environmental and economic performance of industry in order to meet the future needs of its population, government and other stakeholders.

Manufacturing processes of South African companies are characterised by various environmental aspects, such as generation of hazardous wastes, high water consumption and water pollution [EMG, 1993]. The main reason why the production of hazardous wastes is relatively high is the low disposal costs for wastes. Water consumption and its pollution are a keyissue in South Africa because problems with the water supply can result, if no effective measures are taken [Ast v. et al, 1996]. Therefore, the South African manufacturing sector needs to be more controlled in order to limit its environmental effects as much as possible.

Small and Medium-sized Enterprises (SMEs) are defined as companies with between 5 and 200 employees [Prodder Newsletter, 1994]. Although SMEs have a low individual contribution towards environmental effects, they play an important role in solving environmental problems because their total environmental impact is significant. The importance of SMEs for the South African economy is significant as they represent approximately 28.7% of the South African enterprises, while micro-sized enterprises constitute 47.4 % of the enterprises in South Africa [DTI, 1998].

Waste minimisation (WM) practices of SMEs have already been successfully and extensively applied in a large number of countries; viz. the Netherlands, USA, United Kingdom, India and China [van Berkel, 1995], [van der Meer, 1998]. It is also becoming increasingly important for the survival and environmental improvement of the South African manufacturing sector [Maharaj, 1999]. A waste minimisation assessment is a systematic planned procedure with the objective of identifying ways to reduce or eliminate wastes. By conducting a waste minimisation assessment, a company generating waste can identify means of saving money in terms of raw material and manufacturing costs and decreased landfill disposal costs. However, it is believed that the waste minimisation methodology can only partly contribute to a marked improvement in the environmental performance of SMEs in the South African manufacturing sector.

The WM methodology tends to address environmental problems only within the company's physical boundaries. In most cases, these boundaries do not exceed the company's production terrain [Kothuis & Petrie, 1997]. Waste minimisation techniques are the creative methods used to generate options, ideas and opportunities to minimise the waste generated by the company [Jänisch, 2000]. These techniques can be grouped into two approaches, namely source reduction and recycling. Unfortunately, these two approaches can not eliminate all generated waste. Due to process inefficiencies, and technical and economic constraints, there will always be a need for external recycling, energy/material recovery and waste treatment. These approaches are not incorporated into the WM methodology. Additionally, the main focus of a waste minimisation assessment seems to be on wastes directly associated with the company's production process and its waste treatment processes. Certain environmental problems might, therefor, not be addressed. Another limitation of the WM methodology and its application in South Africa concerns the lack of available expertise and financial support in South Africa.

The benefits of waste minimisation will fail to reach most SMEs in South Africa because SMEs, for the most part, do not possess the environmental awareness, knowledge and financial resources to apply waste minimisation practices themselves. It is therefore believed that SMEs should be linked with or helped by external parties to improve their environmental performance. Literature and case-studies revealed that environmental and economical improvement opportunities can be found through the networking of businesses [Berkel et al., 1995], [Côté et al., 1994], [Cramer, 1996], [Nesheim & Reve, 1996], [Lichtenstein & Hoeveler, 1996], [Lowe et al., 1997]. Working together means that common problems are solved and shared challenges are faced more effectively and efficiently. After all, a company together with its partners can achieve more than what a company can achieve on its own.

The observations, as outlined above, have laid the foundation for the formulation of the central problem of this Masters research project, namely the perceived limited ability of SMEs in the South African manufacturing sector to improve their environmental performance on their own. The observations and bodies of theory that may possibly provide solutions to the central problem are explored in detail in the literature review (Chapter 2).

It is hypothesised that the eco-efficiency of an SME can be improved by changing the intensities, connections and contents of the material, financial and information flows between the SME and one or more of its network partners (eg. suppliers, clients, waste treatment companies).

In this thesis, an industrial network is defined as a web of organisations connected directly or indirectly by material, financial and information flows of different magnitudes. Figure 1.1 represents the industrial network model from the point of view of a small manufacturing enterprise, as proposed, though not published by Kothuis and Petrie [1997]. The material, financial and information linkages between the SME and its partners are illustrated in the industrial network model by different types of arrows. The SME is found in the center of its network.

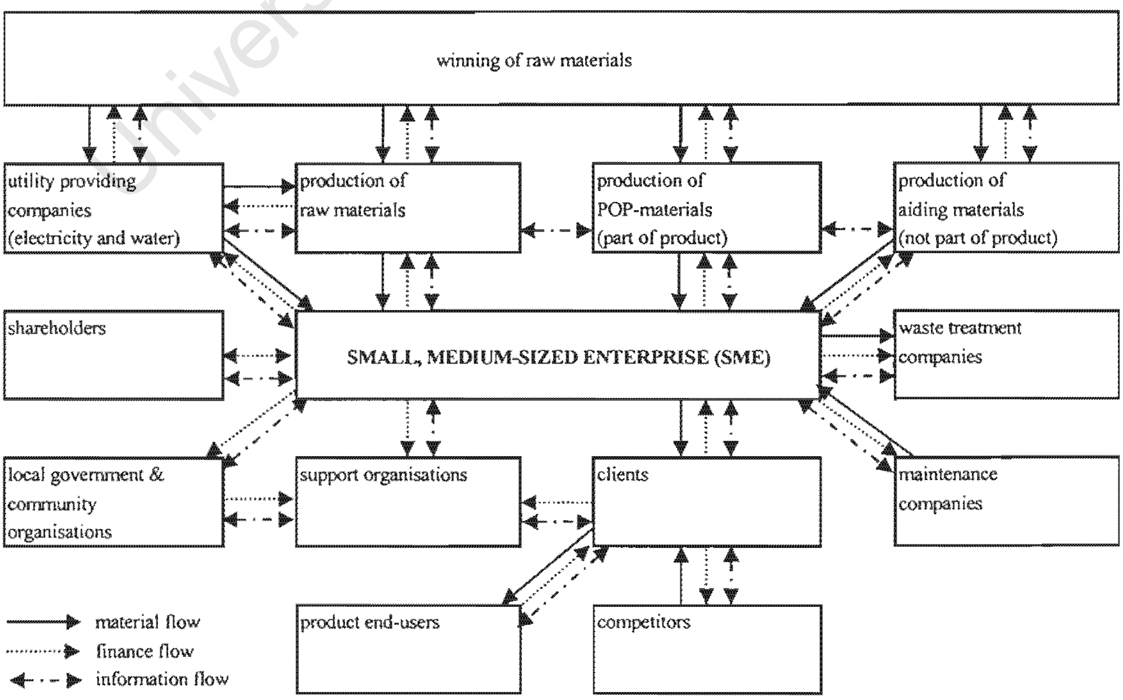


Figure 1.1 Industrial Network Model of an SME [Kothuis & Petrie, 1997]

1.2 Place of this thesis in the Research Project "Industrial Symbiosis View of SMEs"

This Masters research project was initiated and conducted within the framework of the research project "An Industrial Symbiosis View of SMEs: Targeting Greater Eco-efficiency through Innovative Business Practice" of the University of Cape Town, Department of Chemical Engineering [Kothuis & Petrie, 1997]. Ten SMEs participated in the overall research project, with five companies in the textile industry and five companies in the metal finishing industry.

The textile and metal finishing sectors were selected for the industrial symbiosis research project because they have been identified as the 3rd and 4th most polluting sectors in South Africa [EMG, 1993]. The 1st and 2nd most polluting sectors are the mining and the chemical industry. However, mainly large companies operate in these two sectors and not SMEs.

Both the textile and the metal finishing sectors use large quantities of water, pollute the wastewater with heavy metals, dyes and other chemicals, and have a high energy-use during their production process. In both sectors, companies are predominantly SMEs. There is considerable information available on the environmental performance and cleaner technologies of these sectors, from different national and international sources.

The experimental work of this Masters project was conducted at two case-study companies participating in the research project "Industrial Symbiosis View of SMEs", namely a textile printing company and an aluminium products powder coating company.

1.3 Thesis Outline

1.3.1 Key Questions

The key questions for this Masters project are formulated as:

- What are the limitations of the WM methodology to achieve the required environmental improvement of SMEs in the South African manufacturing sector?
- What are the opportunities offered by the theory and case-studies that relate to businesses networking and industrial ecology and that can help SMEs to improve their environmental performance with assistance from their business partners, such as suppliers, clients and support organisations?
- Can a methodology be developed that enables an SME to improve its eco-efficiency with assistance from or in co-operation with partners in the industrial network in which the SME operates naturally?
- Can the developed methodology be applied successfully in two SMEs, in the textile industry and the metal finishing industry respectively, and does it identify eco-efficient improvements in the industrial network of the SME which would not have been identified by a waste minimisation assessment?

1.3.2 Objectives

Specific goals of the research project can be summarised as follows:

1. conduct a literature study on the environmental performance of the South African manufacturing sector and SMEs in particular, classical environmental improvement approaches and the emerging opportunities offered by networking of businesses and industrial ecology;
2. develop a methodology that illustrates the industrial network of an SME, based on the industrial network model [Kothuis & Petrie, 1997];

3. develop a methodology for the identification of eco-efficient improvement opportunities in the industrial network of an SME;
4. test the developed methodology on an SME in the textile industry and one in the metal finishing industry;
5. evaluate and discuss the experimental results in order to validate the formulated hypothesis;
6. If appropriate, revise the industrial network approach based on the evaluation and discussion of the experimental results.

1.3.3 Hypothesis

By answering the key questions and meeting the formulated objectives, it is believed that the following hypothesis can be validated:

"Feasible eco-efficient improvement opportunities can be found within the industrial network of an SME which would not have been identified by a waste minimisation assessment".

1.3.4 Assumptions and Constraints

The validation of the formulated hypothesis will be based on the results of the experiments conducted with the two case-study companies.

The assumptions and constraints that were used validate the hypothesis are discussed below.

<u>Feasibility</u>

An improvement option within the company's industrial network must be environmentally, economically, technically and socially feasible for the SME on which the developed methodology is tested. The ideal situation is that the improvements are beneficial for both the SME and its network partners because only then is there an incentive for all participants to co-operate.

An improvement opportunity is considered to be environmentally feasible if the overall rating of the seven key-dimensions of eco-efficiency improves significantly within the industrial network. Each key-dimension of eco-efficiency will be rated according to subjective categories because it is not viable, time-wise, to conduct a detailed environmental feasibility study on all potential improvement options.

An improvement option is considered to be economically feasible if the simple payback period of the required investments does not exceed three years for any of the involved network partners.

The framework for the technical feasibility study depends on the type and characteristics of the improvement option. The following criteria will be, at least, taken into account:
- What is the availability of required technology in South Africa?
- Was the technology recently developed or has it already proven itself?
- What is the required skills-level of the employees who have to work with the equipment?
- Does the supplier of the technology provide good service during and after installation of the equipment?

A social feasibility study should assess the expected barriers and opportunities related to the willingness and motivation of the SME and its (involved) network partners to co-operate with each other.

Eco-efficiency

Eco-efficiency is a management approach, developed by the World Business Council for Sustainable Development (WBCSD), that allows companies to improve their environmental performance while meeting the demands of the market. Put in simple terms, eco-efficiency – a combination of the words economic and ecological efficiency – is all about producing more with less [DeSimone and Popoff, 1997]. Eco-efficiency was defined at the first Antwerp Workshop on Eco-efficiency, held in November 1993, as being "reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity".

The WBCSD has identified seven success factors for eco-efficiency:
- reduce the material intensity of goods and services
- reduce the energy intensity of goods and services
- reduce toxic dispersion
- enhance material recyclability
- maximise sustainable use of renewable resources
- extend material durability
- increase the service intensity of goods and services

Small and Medium-sized Enterprises

An SME can be defined in a number of ways. This research project applies the SME-definition as defined by the South African Small Business Enabling Act (draft). According to this act, an SME can be defined by quantitative and qualitative criteria, which are presented in Table 1.1.

Quantitative criteria (a minimum of two to be satisfied)				
Sector	Size	Total annual turn-over	Total asset value (fixed property excluded)	Total number employees full-time
Group A		**Less than**	**Less than**	**Less than**
Agriculture, forestry, and fishing, transport, storage and	Medium	R15.0 m.	R3.0 m.	51 – 100
communication, financing, insurance, real estate and	Small	R2.5 m.	R0.5 m.	5 – 50
business services, community, social and personal services	Micro	R0.5 m.	R0.1 m.	1 – 4
Group B		**Less than**	**Less than**	**Less than**
Mining and quarrying, manufacturing, electricity, gas	Medium	R25.0 m.	R5.0 m.	51 – 200
and water, construction, wholesale and retail trade,	Small	R5.0 m.	R1.0 m.	5 – 50
catering and accommodation services	Micro	R1.25 m.	R0.25 m.	1 – 4
Qualitative criteria (compulsory)				
"The enterprise must be privately, and independently owned or co-operatively owned and managed and must not form part of an enterprise which exceeds the qualitative criteria referred to, but may have more than one branch."				

Table 1.1 Definition of SMMEs Proposed in the Draft National Small Business Enabling Act (South Africa)

1.4 Research Approach

This research project can be divided into 4 areas, namely:
- literature review
- methodology development
- practical experiments
- evaluation of methodology

The aim of the literature review is to discuss the observations that have laid the foundation for the formulation of the central problem of this research project. It also explores bodies of theory that may (possibly) provide solutions to the central problem, which is formulated as the perceived limited potential for South African SMEs in the manufacturing sector to improve their environmental performance on their own.

Topics of the literature review:
- The poor environmental performance of the South African manufacturing sector.
- The characteristics of SMEs and their lack of capacity to improve their environmental performance themselves.
- The waste minimisation methodology and its limitation in achieving the required environmental improvement of SMEs in the manufacturing sector.
- Opportunities offered by the theory and case-studies related to networking of business and industrial ecology.

The lessons of the literature review are applied so as to develop an appropriate methodology for the identification of eco-efficient improvements in the industrial networks of SMEs.

The practical experiments concern the application of the developed methodology on two SMEs in the South African manufacturing sector. Based on the practical experiments, the methodology is evaluated in order to determine whether it is an appropriate tool to be used by SMEs.

1.5 Structure of Thesis

Chapter 1 "Introduction" introduces the industrial network approach and provides an overview of the hypothesis and objectives.

The observations that led to the initiation of this research project are elaborated in **Chapter 2 "Literature Review"**; this chapter sets out the theoretical framework of the industrial network approach.

Chapter 3 "A Methodology for the Assessment of an Industrial Network" describes the methodology developed for the identification of the eco-efficient improvements in the industrial networks of SMEs, which is referred as an industrial network assessment.

In **Chapter 4 "Application of the Method to a Medium Enterprise in the Textile Sector"**, the experimental results obtained by the application of the industrial network assessment at a textile printing company are described and evaluated.

The experimental results of the developed methodology at a powder coating company are described and discussed in **Chapter 5 "Application of the Method to a Small Enterprise in the Metal Finishing Sector"**.

Chapter 6 "Evaluation of the Industrial Network Approach" evaluates the developed industrial network approach, based on the conducted experiments with the two case-study companies. The strengths and weaknesses of the developed methodology are addressed in order to elaborate on the extent to which the methodology meets the expectations. By doing this, suggestions can be made for further development of the industrial network approach.

Chapter 7 "Discussion and Conclusions" draws conclusions based on the findings of the previous chapters in order to validate the formulated hypothesis.

Network Impact Matrix	Environmental concerns					
	Material choice*	**Energy use***	**Solid residues***	**Liquid residues***	**Gaseous residues***	**Total**
Network sections:						
Pre-manufacturing	0 – 4	0 – 4	0 – 4	0 – 4	0 - 4	Sum/20
Product manufacturing by company	0 – 4	0 - 4	0 - 4	0 – 4	0 - 4	Sum/20
Product packaging and transport (to & from company)	0 - 4	0 - 4	0 - 4	0 – 4	0 - 4	Sum/20
Product handling by 1st, 2nd, 3rd tier clients	0 - 4	0 - 4	0 - 4	0 – 4	0 - 4	Sum/20
Waste processing by recycling / waste treatment companies	0 - 4	0 - 4	0 - 4	0 – 4	0 - 4	Sum/20
Total score	Sum/20	Sum/20	Sum/20	Sum/20	Sum/20	Sum/100

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)

Table 3.4 Framework for the Network Impact Matrix (after Graedel [1998])

Experiences, as discussed in the literature review, indicate that a full quantitative LCA is not feasible for SMEs due to the lack of time, knowledge and finance [Guld, 1998]. However, the abridged LCA method described by Graedel [1998] works with subjective ratings for the various environmental concerns (material choice, energy use, solid residues, liquid residues and gaseous residues) and can be done with much less time and financial investment. As the ratings of the environmental concerns are subjective, it is important to discuss the network impact matrix with various industry and LCA specialists and to consult available literature. This will prevent ratings from being incorrectly interpreted and/or certain network improvements being unidentified. The scoring guidelines and protocols for an abridged life cycle assessment, as described in Graedel's work, can provide assistance for assessing the environmental concerns for each life cycle stage or network section. These guidelines are included in Appendix D.

The network impact matrix will largely be based on information gathered during step 1 of the developed procedure for the industrial network assessment, the mapping of the industrial network, and readily available data from other external resources.

3.8 Step 5: Summarise the Potential Improvement Opportunities

3.8.1 Purpose

The network brainstorming session and network impact matrix will identify potential network improvements. To streamline the discussions with staff members, the results of these two techniques have to be summarised as managers of SMEs often have a time-constraint. Their time should therefore be used as efficient and effective as possible. It is not feasible, time-wise, to discuss the findings of the brainstorming session and network impact matrix in great detail.

2 Literature Review

2.1 Introduction

The central problem this Masters thesis is investigating is the perceived limited potential of South African SMEs in the manufacturing sector to improve their environmental performance on their own. The literature review explores this perceived problem and discusses bodies of theory that may possibly provide solutions.

As explained in Chapter 1, the introduction, various observations have laid the foundation for the development of an industrial network approach. In this literature review, these observations will be discussed in detail in order to justify the development of the industrial network approach.

Section 2.2 discusses the poor environmental performance of the South African industry and its manufacturing sector. The characteristics of SMEs and their lack of capacity to improve their environmental performance themselves are outlined in Section 2.3. Section 2.4 discusses the waste minimisation methodology and its limitations to achieve the required environmental improvement of SMEs in the manufacturing sector. Opportunities offered by the theory / case-studies related to networking of businesses and industrial ecology are discussed in Section 2.5.

After discussing the observations which initiated the development of a method for the systematic identification of opportunities for improved environmental performance in industrial networks, two useful concepts for the method development are examined; viz. the systems analysis theory and the methodology for a life cycle assessment.

At the end of this chapter, conclusions are drawn about the need for an industrial network approach for SMEs and which features such a tool should possible have.

2.2 The South African Industry and its Manufacturing Sector

This section gives a brief overview of the South African industry and its manufacturing sector with specific reference to the environmental performance of the manufacturing sector.

2.2.1 General Overview

Although South Africa represents only 3% of the continent's surface area, it accounts for about 40% of Africa's industrial output, more than half of the generated electricity, 25% of GDP and 45% of the mineral production of the African continent. Based on these figures, it can be stated that the South African economy is the single most important one on the African continent [Mbendi, 1998]. However, South Africa's economy is characterised by low productivity, a poor international competitiveness, an unequal distribution of income and over-concentration of various industries and other structural problems impeding sustained economic growth and human development [Coleman, 1997].

According to Statistics South Africa [1999], the manufacturing sector can be divided into the following major divisions:
- food products, beverages and tobacco products
- textiles, clothing and leather goods
- wooden products (except furniture), articles of straw and plaiting materials, paper and paper products, publishing, printing and reproduction of recorded media
- coke, refined petroleum products and nuclear fuel, chemicals and chemical products, rubber and plastic products
- other non-metallic mineral products
- basic metals, fabricated metal products, machinery and equipment and computing machinery
- electrical machinery and apparatus
- radio, television and communication equipment and apparatus; medical and precision and optical instruments, watches and clocks
- transport equipment
- furniture
- other

The manufacturing sector makes a significant contribution to South Africa's GDP. The manufacturing sector consists of approximately 26,000 enterprises. Most of these enterprises are located in the province Gauteng (44%), followed by the provinces Kwazulu-Natal (20%), the Western Cape (18%) and the Eastern Cape (6%) [Statistics South Africa, 2000].

Although the manufacturing sector has an increasing GDP index over the past 8 years, the following factors limited the growth of this sector during this period [Naumann, 2000b]:
- an unstable political situation that sent mixed signals to manufacturers;
- unsatisfactory labour relations and rising real wage costs;
- lack of training;
- outdated technology;
- high domestic interest rates and lack of access to international capital markets;
- the declining value of the South African Rand.

2.2.2 *Environmental Performance of the South African Industry and its Manufacturing Sector*

2.2.2.1 *The South African Industry*

South Africa has characteristics of both developed world environmental problems (for example acid precipitation), and undeveloped world environmental problems (for example erosion). Furthermore, the different aspects of the environment have not received equal attention in the past.

Industrial development has, in the past, occurred on a rapid scale, especially around the five major cities in South Africa (Johannesburg, Durban, Cape Town, Pretoria, Bloemfontein). The highest concentration of industry, population and pollution lies within a radius of 150 km of Johannesburg.

According to Bethlehem & Goldblatt [1996], there are three factors that characterise the South African industry sector from an environmental point of view. Firstly, it relies highly on industries with energy-intensive processes dependent on the low electricity prices. Besides this, the industry has a set of old capital stock because of South Africa's long absence and lack of access from world markets, and the consequential low levels of foreign investment during the "apartheid" years. Old capital stock means that technologies are often outdated, and processes with a low(er) environmental impact are not used much by the South African manufacturing industry. Thirdly, those industries involved in the extraction of non-renewable resources, essentially mining and minerals processing, provide a major contribution to the GDP, export rates and employment levels.

One of the major environmental problems in South Africa concerns the incompetence of the government to tackle environmental problems in industry. In the past environmental problems caused by industry have never been a major issue, so there is a lack of environmental policies. Currently, an important development is taking place in the way pollution in industry is dealt with; namely a shift from fragmented pollution control activities and policies towards Integrated Pollution Control (IPC). This IPC principle is incorporated into the newly developed environmental legislation. [RSA, 2000]. Various laws, policies and plans have been introduced in order to bring about cleaner production and pollution prevention within industrial firms, eg. the National Waste Management Strategy (NWMS). The problem with these new policies is that the responsibility for the enforcement and implementation is fragmented among many government departments. This is the reason why a central executing role for the Ministry of Environmental Affairs and Tourism is difficult to realise [Scholten, 1995]. Another problem concerning environmental policies is that there is a lack of money and educated inspectors to control the enforcement of environmental legislation in the industry sector.

The South African economy and environment currently face many challenges which have to be addressed in an effective way in order to obtain sustainable growth in this country. A large part of these problems is due to the country's political past. Fuggle and Rabie [1994] state that the great environmental and economic tasks facing South African policy-makers in the nineties and beyond are to:

- control the exploitation of common property resources
- adopt an effective population policy
- develop instruments for accomplishing an equitable distribution of income and wealth
- identify levels of maximum sustained yield for renewable resources, and
- calculate optimum depletion rates over time for non-renewable resources

2.2.2.2 *The South African Manufacturing Sector*

The Environmental Monitoring Group [1993] conducted a study on the environmental problems of the manufacturing sector in South Africa. This study included the chemical process, pulp and paper, mineral benefication, heavy engineering, electronics, automotive, textiles and clothing, food processing and building materials industries. Table 2.1 gives an overview of the environmental and health effects of the waste types and identified pollutants of the selected manufacturing sectors.

Pollutant	**Environmental / health effect**
acids	corrosive attack, solubilises metals
alkalis, sodium	increased alkalinity and salinity; toxic to fish; solubilises metals
aluminium	soluble aluminium implicated as neurotoxin; solubilises under acid or alkali conditions
ammonia	solubility in water results in alkaline conditions; eye, nose, throat and respiratory tract irritation
cadmium	highly toxic and cumulative poison; carcinogenic
carbon oxide	global warming
carbon monoxide	neurotoxin at high concentrations
chlorinated organics / hydrocarbons	carcinogenic; flammable
chlorofluorcarbons (CFCs)	ozone depletion
colour	visually objectionable; can reduce light penetration of water
cyanide	toxic at low concentrations – higher toxity under acidic conditions; bioaccummulative
detergents	foaming (contain phosphates)
fluoride	chronic toxicity at concentrations not much higher than beneficial level for dental care
heavy metals eg. cadmium, cobalt, chromium	persistent, bioaccumulative, toxic contamination of soil and ground water; toxic to bacterial and aquatic life; inhibits sewage treatment operation
hydrocarbons – dioxins and furans	toxic; carcinogenic
hydrogen sulphide	odorous at low concentration levels; toxic
inorganic salts eg. chlorides and sulphates	increases water salinity; corrosive attack on construction materials; inhibits biological activity
insecticides; pesticides	toxic to most forms of life; inhibits biological activity
nitrates and phosphates	nutrient for algal growth which causes oxygen depletion
nitrogen oxides (NOx)	irritant: respiratory problems; contributes to formation of photochemical smog
oil and grease	blockage of sewer lines and equipment; water scum; anaerobic conditions; odour; may lead to formation of free fatty acids with resulting acid/corrosive attack on concrete (damage to sewer systems)
organic compounds	overloading of conventional sewage treatment plants; depletion of oxygen in rivers
particulate matter in air	respiratory problems
pathogens	bacteria and viruses which cause disease
phenols	high oxygen demand leading to oxygen depletion; unpleasant odour from contaminated water
polychlorinated biphenyls (PCBs)	persistent, bioaccumulative toxic

Pollutant	Environmental / health effect
sulphides/sulphates	may evolve noxious gases; dissolution in water creates acidic conditions resulting in corrosive attack
sulphur oxides (SOx)	irritant; respiratory problems; contributes to formation of acid rain
suspended solids (SS)	turbidity and solids deposition impede transfer of oxygen and reduce light penetration of water; inhibiting biological growth
temperature	thermal pollution; promotes abnormal algal growth in natural water bodies; may cause structural damage to sewer system; may inhibit biological treatment processes
volatile organic compounds (VOCs)	odorous; contributes to the generation of photochemical smog

Table 2.1 Environmental and Health Effects of Waste Types and Identified Pollutants [EMG, 1993]

The relatively low costs of raw materials, many of which are mined in South Africa, and especially the low disposal costs for wastes, do not encourage industry to make efficient use of natural resources. This is the main reason why the production of wastes by the South African manufacturing sector is relatively high. In the last years, many licenses have been given to new waste disposal sites without fully examining and assessing their potential long-term environmental impacts. This happened because the Department of Water Affairs and Forestry had a lack of inspectors to enforce regulations. A significant number of landfill facilities cause water, soil and air pollution, which is caused much controversy especially in surrounding comunities. [Ast v. et al., 1996]. Figure 2.1 and Figure 2.2 show a comparative contribution to respectively total industry waste and hazardous industry waste by the selected manufacturing industries [EMG, 1993].

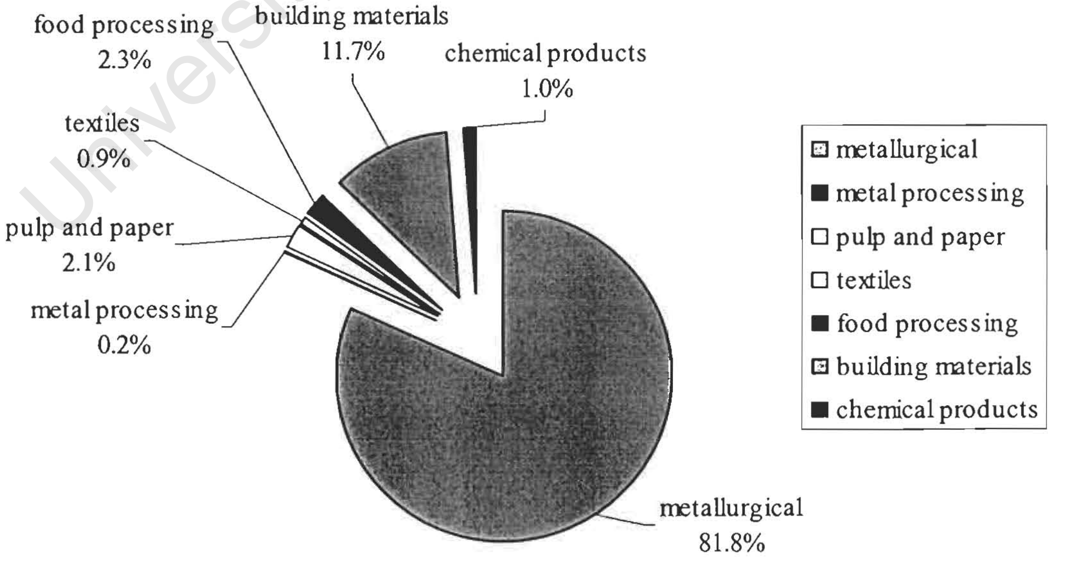


Figure 2.1 Comparative Contribution to Total Industry Waste by the Manufacturing Sectors [EMG, 1993]

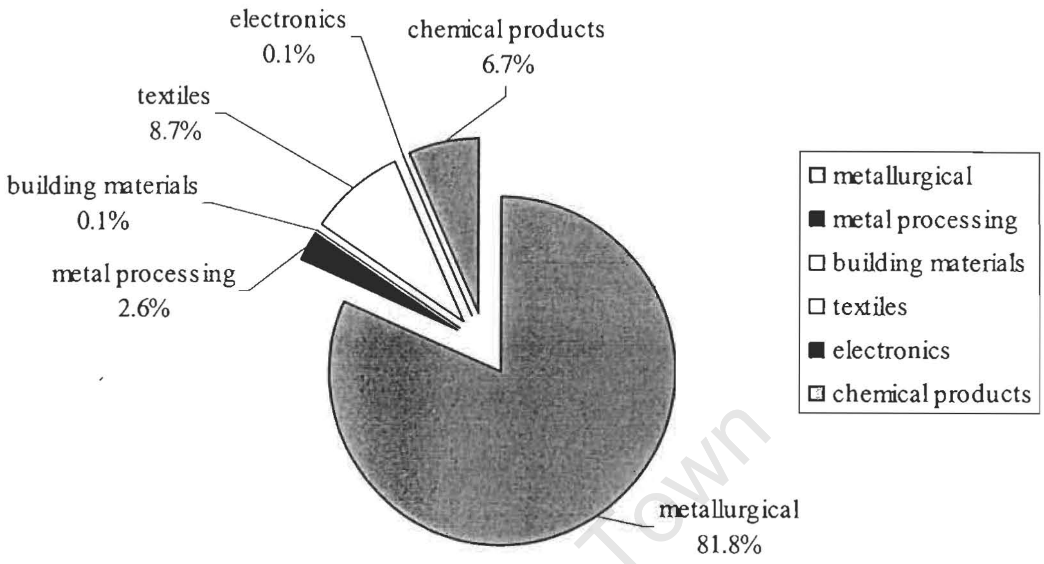


Figure 2.2 Comparative Contribution to Hazardous Industry Waste [EMG, 1993]

In South Africa, water is not abundantly available: rivers and artificial lakes must provide most of the water. Although South Africa is able to meet the water demand at present, problems with the water supply can be expected if no measures are taken to improve the efficiency of water use, storage, and transport. Pollution and salination of water stocks, caused primarily by the manufacturing sector, have a significant negative effect on the natural environment [Ast v. et al, 1996]. Table 2.2 gives insight into the water intensity of various processes in the manufacturing sector.

Process	**Water intake per unit**
Wool, dyeing and finishing	100 – 600 m3 per ton
Cotton, wet processing	80 – 600 m3 per ton
Wool, washing	7 – 40 m3 per ton
News printing	17 – 30 m3 per ton
Kraft pulp production, unbleached	12 – 15 m3 per ton
Cardboard manufacturing	1.5 – 22 m3 per ton
Breweries	8 – 13 liter per liter product
Abattoirs, with meat canneries	0.8 – 20 m3 per cattle unit

Table 2.2 Water Consumption per Produced Unit for Selected Processes [WRC, 1983]

2.2.2.3 *Overall Environmental Overview of the Manufacturing Sector*

Table 2.3 gives an overview of the environmental aspects of various manufacturing sectors in South Africa, as selected by EMG [1993]. This table shows that the manufacturing processes have various environmental aspects. Therefore they need to be controlled in order to limit their environmental effects as much as possible.

Sub-sector	Critical aspects	Estimated total waste intensity (T/R million GDP)[3]	Estimated hazardous waste intensity (T/R million GDP)[4]	Estimated electrical power intensity (GWh/R million GDP)[5]	Water use	Water pollution [7]	Air pollution	Land pollution
Chemical products	energy; air pollution; hazardous waste	3.9	1.8	1.4	high	high	high	high
Metallurgical	energy; air pollution; hazardous waste	719.3	47.7	7.2	high[6]	high[8]	high	high
Metal processing	waste water; hazardous waste	3.3	2.7	0.1	medium	high	low	high
Automotive[1]	energy; air pollution; solid waste	part of metal processing	part of metal processing	part of metal processing	medium	high	high[9]	high
Electronic	toxic gases; hazardous waste	0.2	0.2	unknown	medium	high	medium	high
Pulp and paper	energy; water use; waste water; air pollution	36.1	0.0	1.1	high	high	high	medium
Textiles	water use; waste water; hazardous waste	23.6	14.5	0.4	high	high	low	medium
Food processing	water use; waste water	10.6	0.0	0.1	high	high	low (odour)	high
Building materials[2]	energy; air pollution	408.4	0.3	1.8	low	medium	high	medium

Notes:

1 incl. of broader issues relating to "transportation"
2 chiefly in relation with to cement production as addressed in [EMG, 1993]
3 based on CSIR [1992] total waste estimates and 1991 GDP data
4 based on CSIR [1992] hazardous waste estimates and 1991 GDP data
5 based on ESKOM record of sales for 1991; expected to be underestimated due to exclusion of contribution from bulk sales and industry self-production
6 even with high level of water recycling
7 refers to pollution load
8 contamination from landfill and process run-off
9 with respect to the air pollution impact of "transportation"

Table 2.3 Overview of Environmental Aspects of Selected Manufacturing Sectors [EMG, 1993]

2.3 Small and Medium-sized Enterprises

Although SMEs have a low individual contribution towards environmental degradation, they could play an important role in solving environmental problems because their collective environmental impact is significant. The importance of SMEs for the South African economy is significant as they represent approximately 28.7% of the South African enterprises while micro-sized enterprise constitute another 47.4 % of the total number of enterprises in South Africa [DTI, 1998].

This section discusses the difficulties of SMEs to address environmental problems themselves. Additionally, some co-operative solutions for SMEs are outlined in this section.

2.3.1 Environmental and Economic Problems Faced by SMEs

A common problem is that managers of SMEs do not have access to, and as a result are not aware of, information concerning environmental problems and effects. Besides this, many SMEs do not have the financial resources and the knowledge to solve their environmental problems on their own [Welford & Gouldson, 1993].

In South Africa, there is a lack of co-ordinated control on observing the environmental legislation by the industry. South African companies with international clients will comply with certain environmental standards (eco-labelling, ISO 14001) and large companies generally tend to reach an acceptable environmental standard through a mixture of regulation and voluntary action. Environmental management practices of SMEs (management, controlling of processes, waste disposal, housekeeping), in developing countries such as South Africa, are in general regarded as being of a low standard; the controlling by governmental institutions on observing environmental legislation at SMEs is therefore important.

The low costs of dumping waste and the fact that in developing countries regulations are barely strictly enforced does not encourage SMEs to take environmental action. The lesser financial resources of SMEs and smaller scales of operation also do not attract the commercial interest of consultants and equipment suppliers or commercial research and development [Selvam & Chandak, 1992].

According to Hayes [1997], the top ten mistakes made by SMEs are:

1. *Insufficient capital:* there is no buffer for unexpected expenses or for quieter times;
2. *No business plan:* many SMEs loose (or do not have) focus on the right strategic course;
3. *No managerial focus:* many managers of SMEs are too busy with day-to-day business that they do not have time to manage their business effectively;
4. *Inadequate records:* the paperwork is forgotten which will lead to problems with government agencies and makes measuring the business performance very difficult;
5. *Lack of profit focus:* many SMEs just focus on surviving and do not know how much profit they need to be making;
6. *Cash flow management:* often SMEs do not differentiate profits and cash flow and get into trouble because they run out of cash;
7. *Inadequate systems:* SMEs depend a lot on the owners' personal abilities, a lack of systems can cause different standards within the firm;
8. *Failure to plan for taxation:* many times an SME fails to manage, fund and plan the tax responsibilities which can lead to severe financial problems.

9. *Inadequate resource management:* it is very important for an SME to manage and control the various kinds of available resources (time, people, plant and equipment, cash, etc) effectively and efficiently.
10. *Break-even point:* effective pricing and costing decisions requires understanding of the break-even point of the firm. AN SME can get in trouble if it trades their products / services under the break-even point.

These categories of mistakes and problems obviously have a negative impact on the SME's economic performance; however, these mistakes can also be linked with their general poor environmental performance. For example, effective environmental management requires adequate resource management (point 9) and sufficient records (point 4). Subsequently, sufficient capital (point 1) is required to invest in the necessary cleaner technologies.

It is thus a wide-held view that SMEs must be assisted to become more resource-efficient, competitive, technically advanced and less environmentally polluting, as it is often difficult for SMEs to achieve these requirements on their own. Only a few SMEs will have the financial resources to hire environmental consultants. Additionally, the technical know-how of large companies to help SMEs with their environmental management might not be suitable for SMEs.

A way to help SMEs to improve their environmental and economic performance will be found around co-operation and networking. This means that links between SMEs themselves and links between SMEs and institutions have to be established. For example, a useful and often unexploited link might be between business and local universities[1] or between firms and economic development units or councils. SMEs can learn from each other's experiences and mistakes if they co-operate and form a network [Welford & Gouldson, 1993]. However, co-operation and networking cause uncertainty, and are difficult to manage thus having a high failure rate. This is the reason why a lot of firms opt for full control of their own business and prefer to expand by internal growth or by mergers and acquisitions [Nesheim, 1996].

2.3.2 Co-operative Solutions for SMEs

In the previous subsection, it was discussed that SMEs require external assistance to improve their environmental performance. This subsection gives some examples of established co-operative solutions for SMEs in South Africa and also discusses problems associated with co-operative practices.

The South African government has presented a white paper, called "National Strategy for the Development and Promotion of Small Business in South Africa" [RSA, 1995b]. This policy document sets out a framework for the establishment of support organisations who are able to provide finance, transfer information on commercial and technical issues, advice, training and education to SMMEs and to facilitate business linkages programmes. It is the vision of the government that these responsibilities will be taken up by NGOs, business organisations and the private sector, with only limited participation by governmental institutions [Coleman, 1997]. Perhaps a similar kind of approach can be applied to tackle problems regarding the enforcement of environmental legislation, as discussed in Subsection 2.3.1.

[1] The Department of Trade and Industry manages the Technology and Human Resources for Industry Programme (THRIP) that aims to enhance competitiveness of the South African industry by encouraging strategic partnerships between industry, research and educational institutions [DTI, 1999]

Local business centres are being established in South Africa to provide business services to SMMEs, like providing specific information and giving advice, networking and sharing of experiences among companies. A good example of a local business centre is the Business Opportunity Network – Western Cape (BON), the mission of which is "to create conditions for the empowerment of SMMEs through business linkages" [BON, 1998]. The main objectives of BON are to facilitate linkages between SMMEs, established businesses and government institutions, to build capacity for SMMEs and to support networking and co-ordination between all organisations related to the development of the SMME-sector.

Until present, the local business service centres have mostly worked together with low-tech business, such as small-scale retailers and catering services. A lack of local capacity in core technology know-how has been recognised, this is a constraint in improving the opportunities of the manufacturing/ high-tech SMEs. Proposals for the establishment of manufacturing technology centres have been developed by the co-ordinating body of the South African government, called the Business Development Service (BUDS). These centres will focus on the different sectors of the industry and provide mainly technical support to SMMEs. The government still has to accept this proposal and funding and collaboration must be sought from large local manufacturing business.

In many countries environmental support programmes for SMMEs have been established, with costs subsidised by national governments or international organisations like the United Nations.

The type of support provided by these programmes can be summarised as [Coleman, 1997]:
- programmes which offer technical assistance co-ordinated by government departments and university based technology centres
- provision of industry related information and specific training courses by trade associations
- provision of grants or loans (low or free of interest) for clean-up, innovative research and pollution control by small business development corporations
- building of centralised waste treatment plants which are better able to treat specific types of wastes, and facilitating economic material recovery
- assistance with implementing environmental management systems, like the ISO 14001 norm

Technical support and providing know-how to SMEs by large(r) companies is possible, but this type of support is limited by possible conflict of interest, and technology / management systems which may not be appropriate for SMEs. Additionally, there can be resistance to financial support over and above internal costs incurred for environmental management [Coleman, 1994].

Rowe and Hollingworth [1996] stated in their work that the role of business-support organisations in providing environmental management, training and support to SMEs is of significant importance. However, SMEs in the United Kingdom have made little use of these services, even when free or subsidised [Smith and Kemp, 1998]. SMEs generally agree that they require external assistance to meet their environmental responsibilities, but this assistance should be locally accessible and include best-practice case-studies relevant to the size and sector of the company [Smith et al., 2000].

2.4 Waste Minimisation as a Tool to Improve Environmental Performance

As outlined in previous sections, the environmental performance of the SMEs in the South African manufacturing sector is poor. Waste minimisation (WM) is proposed to be currently the most appropriate methodology to improve the environmental performance of a company [USEPA, 1988].

According to the National Waste Management Strategy for South Africa, waste minimisation is defined as the reduction, to the extent feasible, of waste that is generated or subsequently treated, stored or disposed of. It includes any source reduction and recycling activity undertaken by a waste generator that result in either (I) the reduction of total volume or quantity of waste, or (ii) the reduction of toxicity of waste, or both, so long as such reduction is consistent with the goal of minimising present and future threats to human health and the environment [PMG, 1998].

Waste minimisation practices have already been successfully and extensively applied in a large number of countries; viz. the Netherlands, USA, United Kingdom, India and China [van Berkel, 1995], [van der Meer, 1998]. Besides the case-studies carried out within the framework of the Industrial Symbiosis project and a case-study conducted at a automotive component manufacturer [Coleman, 1994], the South African industry has limited or no experience with the practical application of waste minimisation.

South Africa can learn from successes and mistakes of other countries, mainly developed countries, regarding the prevention of waste and emissions. The waste minimisation methodology can, therefore, be regarded as a valuable tool to improve the environmental performance of SMEs in the South African manufacturing sector.

The WM-methodology, its value and limitations to improve the environmental performance of the South African manufacturing industry are outlined in this section.

2.4.1 Description of the Waste Minimisation Methodology

By conducting a waste minimisation assessment, a company generating waste can potentially identify means of saving money in terms of raw material and manufacturing costs and decreased landfill disposal costs. The need for waste treatment facilities may be eliminated by applying waste minimisation practices; therefore saving investment and operating costs of so-called "end-of-pipe" facilities as well.

A waste minimisation assessment is a systematic planned procedure with the objective of identifying ways to reduce or eliminate wastes. Various institutions, e.g. the USEPA [1989] and UNEP [1991], have developed similar kinds of methodologies for the conduction of a waste minimisation assessment.

Table 2.4 shows the WM-methodology as developed in the Netherlands [Kothuis & Berkel, 1992]. The reason for choosing the methodology is that this methodology has been tested extensively with successful results in Europe; this methodology also 'comes the closest to convincing a company to incorporate cleaner production in it's business operations' [Berkel, 1995]. This particular WM-methodology has been applied at one of the two case-study companies involved in the research presented in this thesis.

Phase 1: Planning and organisation
- get management commitment - define scope and boundaries of the project - set up a project team and define responsibilities - set up goals (quantitative or qualitative) and time-planning - identify sources of data and contact persons
Phase 2: Pre-assessment
- identify, characterise, and track the facilities waste streams - draw up process flow charts - determine mass and energy flows - start making rough mass and energy balances - identify the main environmental costs - select main focus areas
Phase 3: Assessment
- compile background information on processes, waste types & sources, technologies, wm-practices and environmental impacts - gather additional data - close mass and energy balances - generate options - screen and select options for further study
Phase 4: Feasibility
- technical evaluation - economical evaluation - environmental evaluation
Phase 5: Implementation
- decisions on projects and finances - implementation - evaluate results

Repeat the process

Table 2.4 Waste Minimisation Assessment Procedure [Kothuis & Berkel, 1992]

The goal of the planning and organisation phase is to obtain management commitment and to determine the overall goals, involvement from company staff, and to set up a time-plan for the waste minimisation project. The pre-assessment is an initial overview of the company's operations and waste streams and emissions to establish the focus areas for the waste minimisation assessment. The objective of the assessment phase is to obtain a clear understanding of the sources and causes of wastes and emissions in the focus areas, resulting in the identification of improvement options. It involves a detailed study of the focus areas to establish as many possible suitable waste minimisation options. During the fourth phase, a technical, economical and environmental feasibility analysis is conducted on the generated waste minimisation options. The last phase incorporates the implementation of the feasible waste minimisation options.

2.4.2 Waste Minimisation Techniques

Waste minimisation techniques are the creative methods which are used to generate options, ideas and opportunities to minimise the generated waste by the company [Jänisch, 2000]. Waste minimisation techniques can be grouped into two approaches, namely source reduction and recycling.

Source reduction can be defined as any activity that reduces or eliminates the generation of hazardous waste at the source, usually within the process. Recycling is defined as the reuse and recycling of wastes for the original or some other purpose, such as materials recovery and energy production [CDTSC, 1993]. Of these two approaches, source reduction is preferable to recycling from an environmental point of view as recycling activities themselves consume resources and generate wastes [Coleman, 1994].

Source reduction techniques are characterised as good operating practices, technology changes, input material changes, or product changes. Recycling techniques are characterised as use/reuse techniques and resource recovery techniques. Figure 2.3 visualises the structure of these waste minimisation techniques.

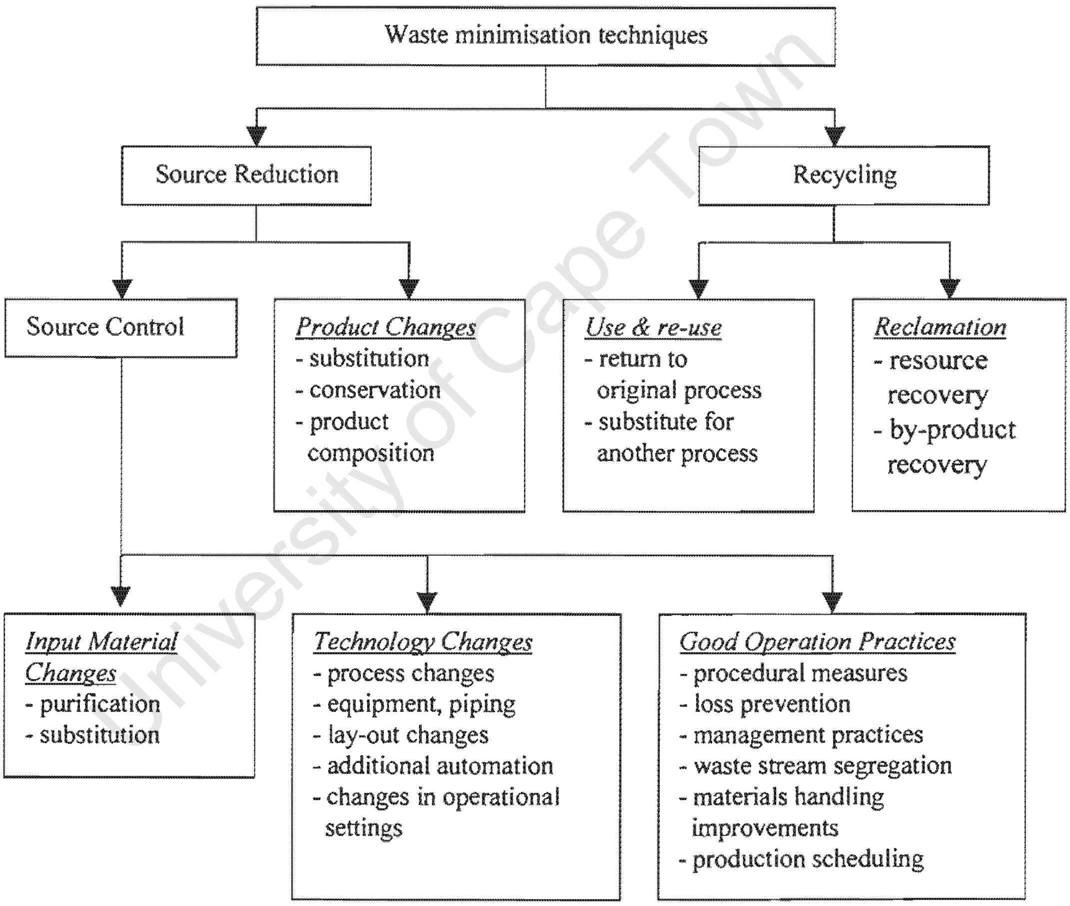


Figure 2.3 Waste Minimisation Techniques [USEPA, 1989]

Source reduction techniques avoid the generation of hazardous wastes, thereby eliminating the problems associated with handling these wastes. Recycling techniques may be performed on-site or at off-site facilities designed to recycle the waste.

2.4.3 *Limitations of the Waste Minimisation Methodology and its Application in South Africa*

This section discusses why it is believed that the waste minimisation methodology can only partly contribute to a marked improvement of the environmental performance of SMEs in the South African manufacturing sector.

The limitation of the WM-methodology and its application in South Africa relate to the systems boundaries, scope and main focus of the waste minimisation. Each limitation will be discussed separately in the following subsections.

2.4.3.1 *Systems Boundaries of the WM-methodology*

The WM-methodology tends to address environmental problems only within the company's physical boundaries. In most cases, these boundaries do not exceed the company's production terrain [Kothuis & Petrie, 1997].

According to the systems theory, as explained in Subsection 2.6.1, only separate elements (sub-systems) of a production system are studied by the WM-methodology, rather than the entire system. Figure 2.4 shows the systems boundaries of the WM-methodology.

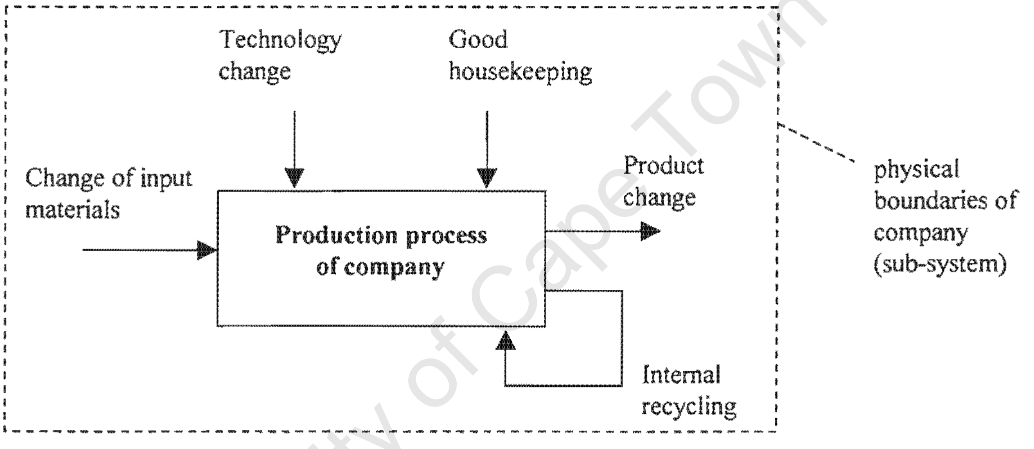


Figure 2.4 Systems Boundaries of the WM-methodology

2.4.3.2 *Scope of the WM-methodology*

As discussed in Subsection 2.4.2, the scope of the waste minimisation methodology includes source reduction and internal recycling. Unfortunately source reduction and recycling techniques cannot eliminate all waste generation. There will always be waste generation given fundamental thermodynamic limits to the efficiency of all processes of conversion, production, consumption and recycling [Jackson, 1991]. Besides these in-efficiencies, technical and economic constraints also play an important role in the generation of wastes. So there will always be a basic need for end-of-pipe-treatment and disposal of wastes.

Figure 2.5 shows the preferred waste management hierarchy, in which waste treatment for pollution control and waste disposal should be considered only after appropriate waste minimisation measures have been taken [Coleman, 1994].

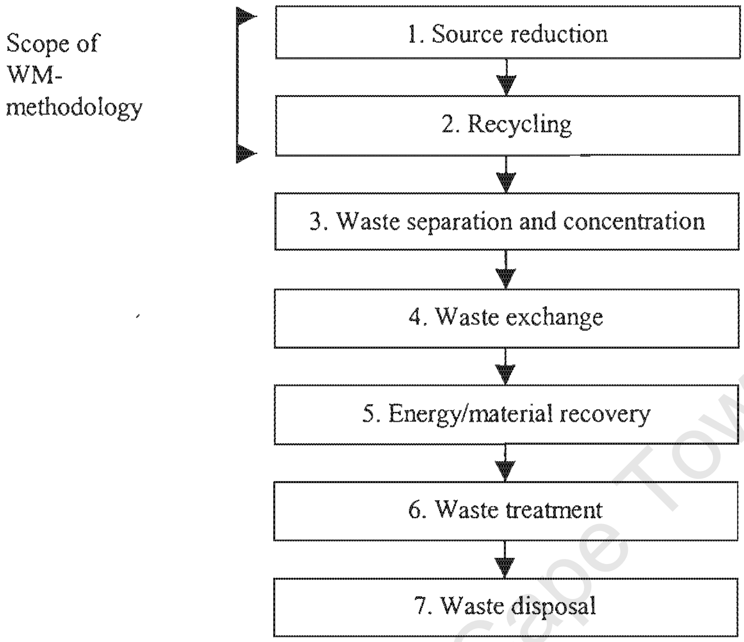


Figure 2.5 The Waste Management Hierarchy [UNEP WG, 1998]

2.4.3.3 *Main Focus of WM-methodology*

The WM-methodology consists of four phases. The goal of the pre-assessment phase is to get an initial overview of the company's operations and waste streams and emissions in order to determine the focus areas for the assessment phase. The collection of data in the pre-assessment phase is largely based on the completion of worksheets. Therefore it can be concluded that the scope or coverage of the worksheets have a significant influence on the selection of focus areas.

Based on a review of various WM-methodologies [USEPA, 1989], [UNEP, 1991], [Kothuis & Berkel, 1992], the most common worksheets used during pre-assessment phase of a waste minimisation assessment are:
- summary of process steps
- overview of main input materials
- waste and emissions
- energy consumption
- costs of wastes and emissions
- evaluation of wastes and emissions

The main focus of the worksheets seems to be on wastes directly associated with the company's production process and its waste treatment processes. Certain environmental problems of a company might not be addressed by a waste minimisation assessment due to the set-up or coverage of the used worksheets. For example the costs and environmental impacts related to the re-working of a product, e.g. to a poor quality, are often not covered by the worksheets during a waste minimisation assessment. In Figure 2.6, the main focus of the WM-methodology is illustrated.

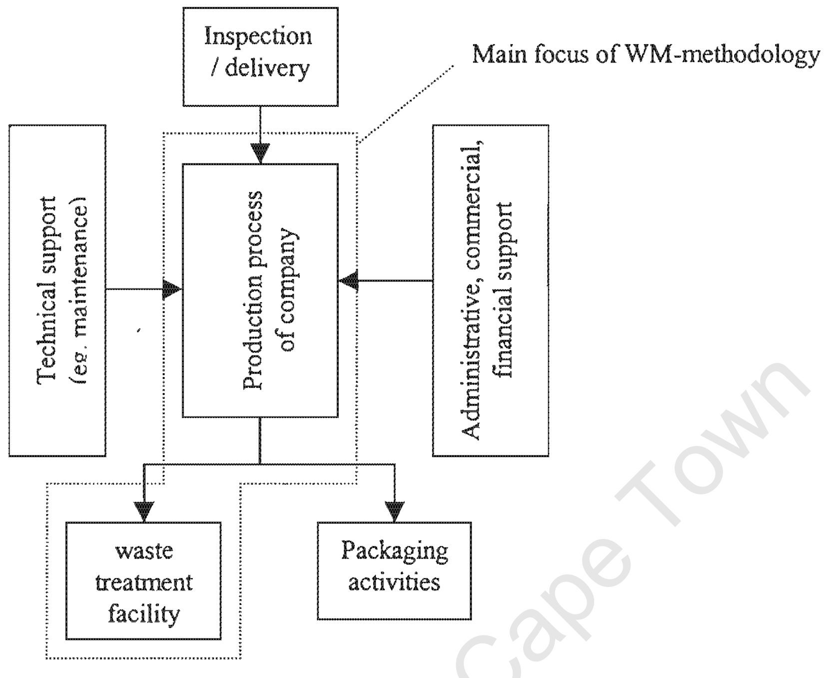


Figure 2.6 Main Focus of the WM-Methodology

2.5 Opportunities Offered by Networking of Businesses

As discussed in Subsection 2.3 "Small and Medium-sized Enterprises", SMEs often lack the expertise, financial and human resources to reduce their wastes and emissions on their own. It is therefore believed that SMEs should be linked with or helped by external parties to improve its environmental performance.

Literature and case-studies have revealed that environmental and economical improvement opportunities can be found by networking of businesses [Berkel et al., 1995], [Côté et al., 1994], [Cramer, 1996], [Nesheim & Reve, 1996], [Lichtenstein & Hoeveler, 1996], [Lowe et al., 1997]. Working together means that common problems are solved and shared challenges are faced more effectively and efficiently. After all, a company can achieve more in partnership than what a company can achieve on its own.

The concept and classification of environmental networking of businesses is explained in Subsection 2.5.1. Additionally, Subsection 2.5.2 outlines the principle of industrial ecology, which is closely linked to environmental networking. Some experiences with environmental networking of businesses are discussed in Subsection 2.5.3 in order to learn from these experiences. Drivers and barriers for networking of businesses and their success criteria are then discussed in Subsection 2.5.4 and 2.5.5.

2.5.1 Networking of Businesses for Environmental Management Purposes

Although not always for environmental improvement purposes, the opportunities of networking of businesses have been explored intensively; viz. Nesheim and Reve [1996], Lichtenstein and Hoeveler [1996]. Valuable lessons for establishing linkages between SMEs and their network partners can be learnt from their research and experiences.

Lichtenstein and Hoeveler defined networking as co-operation of business in order to compete more effectively or to achieve together what each firm could not achieve alone. According to them, a firm can have three reasons to network with other businesses:
- companies might be confronted by the same problem;
- companies might have similar needs;
- companies want to adapt the same technology or manufacturing methods.

This thesis researches the opportunities for SMEs to improve their environmental performance with assistance from, or in co-operation with, its business partners; this implies networking of businesses for environmental reasons.

Networking of businesses for environmental management purposes is classified in this thesis as environmental networking. Based on the definition of Lichtenstein and Hoeveler, environmental networking can be defined as the co-operation of businesses with the aim of achieving a better overall environmental performance than a firm could achieve individually. This definition is broad and covers all environmental management approaches with a co-operative or networking element, such as industrial ecology, life cycle assessment and integrated chain management.

Based on the work of Van Berkel et al. [1995], De Groene and Hermans [1998] and Richert [1995], environmental networking practices can be categorised in the following seven approaches.
- *The material-oriented approach:* analyses the material flows through the entire life cycle of a material in order to identify, evaluate and implement improvement options.

- *The product-oriented approach:* analyses the different material flows of the components of a selected product from a system point of view in order to optimise the product-environment interaction.
- *The waste-oriented approach:* the waste flows of a group of businesses, linked for various reasons (eg. active in same industry, production process) are analysed in order to prevent or minimise the generated wastes by applying the five waste minimisation techniques.
- *The function-oriented approach:* the specific function of a product is analysed, this approach can be used for the comparison of different products with the same function.
- *The production-oriented approach:* the flow of substances within a specific company and its relations with the environment and business partners are assessed.
- *The actor-oriented approach:* assesses the opportunities and constraints for different actors in industry to change material and product flows in an environmentally-compatible direction. The actors can be divided in three main streams: industries, consumers and government.
- *The region-oriented approach:* focuses on optimising the exchange of materials, energy and information between businesses in a certain region.

Figure 2.7 shows how various established environmental assessment tools are related to the distinguished categories for environmental networking.

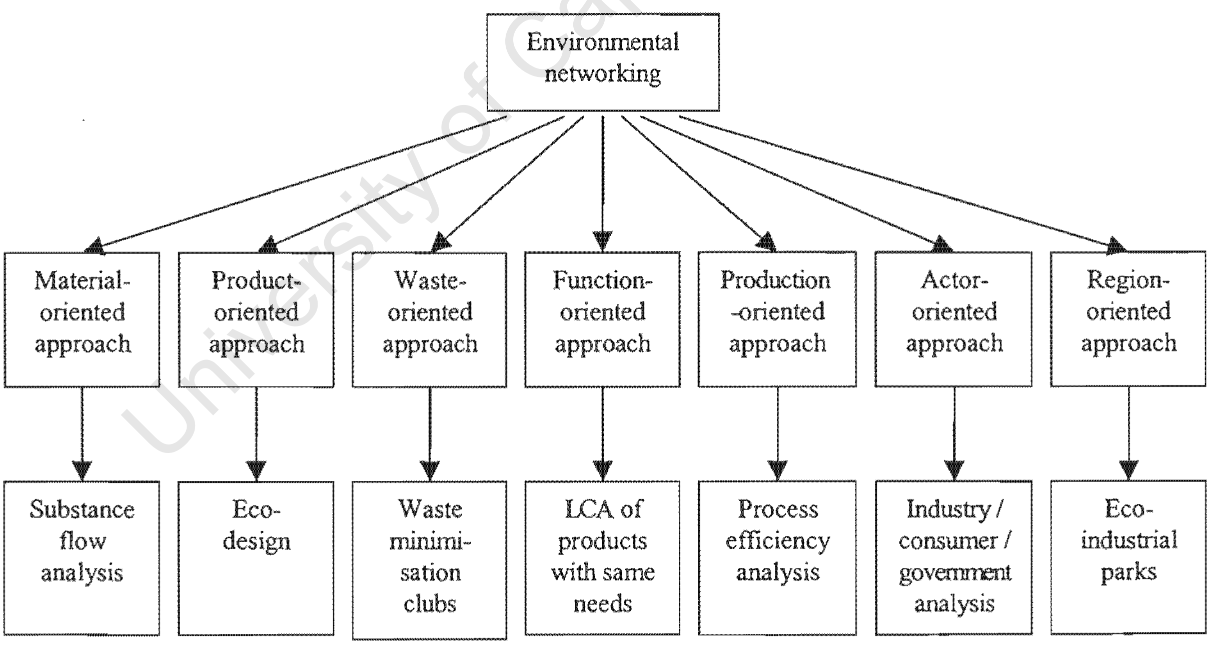


Figure 2.7 Approaches for Environmental Networking

2.5.2 Industrial Ecology

Related to the industrial network model, as shown and discussed in Chapter 1 "Introduction" of this thesis, is the concept of industrial ecology. In contrast with the industrial network model, which is company focused, industrial ecology focuses on entire production systems. However, both concepts go beyond the company's physical boundaries and have a strong networking element.

Jelinksi et al. [1992] defined industrial ecology as 'a concept in which an industrial system is viewed not in isolation from its surrounding systems but in concert with them'. Van Berkel et al. [1995] state that industrial ecology employs a holistic view to study, assess and improve the utilisation of natural resources (materials and energy) in an industrial society.

It is the opinion of the author of this thesis that the emphasis of industrial ecology is on the improvement of material (including energy) efficiencies in industrial systems by establishing of input-output material linkages between manufacturing entities, rather than analysing material flows within independent manufacturing entities. Environmental networking, as described in previous subsection, incorporates all networking activities which are initiated for environmental reasons. The scope of the definition of environmental networking is therefore wider than the industrial ecology definition.

Compared to most environmental improvement tools currently available, such as waste minimisation, industrial ecology offers a radically different approach by viewing a company's process not in isolation from its surrounding systems but in concert with them. By applying a holistic and sub-system exceeding approach, it is proposed that industry, including SMEs, can seek for new creative ways to meet the environmental challenges and opportunities through co-operation of businesses.

In the past thirty to thirty-five years environmental management developed from a gradual awareness of environmental problems caused by industry, to the recent development of the industrial ecology approach.

Erkman [1998] describes the evolution of environmental management focussing on the development of industrial ecology itself. The exploration of the industrial ecology approach started thirty years ago, but until the beginning of the 90s the results of these projects and studies were not really satisfying because they were too theoretical or the industry was not yet ready for the creation of industrial ecology relationships. Researchers from the United States, Belgium and Japan played an important role in discovering the possibilities and problems of industrial ecology. During the last five years the industrial ecology / system approach has been explored and studied quite intensively. The publication of a special issue of the Scientific American called "Managing Planet Earth" in September 1989 can be seen as the source of the current development of industrial ecology. In their paper, Frosch and Gallopoulos [1989] propose that it should be possible to create an industrial production system, which is adapted to the natural ecosystem, that could lead to a more sustainable society. This theory created the idea of the establishment of an industrial ecosystem. The article in the "Scientific American" inspired other researchers to develop the industrial ecology approach and the view of systems analysis further. Among them are Hardin Tibbs, Arthur D. Little and Thomas Graedel.

Until present, there is no standard definition for industrial ecology. Researchers use different definitions and sometimes the difference between industrial and ecology is not made [Erkman, 1997]. There is thus a need to formulate a standard definition of industrial ecology and to set out what its boundaries are. This was also one of the conclusions of the International Conference on Industrial Ecology and Sustainable Development, held in Troyes – France during September 1999.

2.5.3 *Experiences with Environmental Networking of Businesses*

Practical experiences with environmental networking are discussed in order to learn from them while developing and testing the industrial network approach. As shown in Figure 2.7, environmental networking can be distinguished in seven approaches. Experiences with the waste-, actor- and region-oriented approach are outlined in this subsection.

Waste minimisation clubs are seen as a potential means of overcoming the expertise problem of SMEs since these clubs facilitate the sharing of ideas, information and practical experience of waste minimisation as well as providing less expensive expertise [Goff, 1999]. Some international and South African experiences with established waste minimisation clubs are discussed in Subsections 2.5.3.1 and 2.5.3.2. For the waste-oriented approach, two waste minimisation clubs in South Africa and the "Target Zero" waste minimisation club in New-Zealand are discussed.

Additionally, the Skills Supply Chain Programme of Ground Trust in the United Kingdom is outlined; this case-study incorporates the actor-oriented approach. The Kalundborg Ecosystem is the most famous example of an eco-industrial park (industrial ecology) and is discussed as an example of the region-oriented approach.

2.5.3.1 Waste Minimisation Clubs in South Africa (Waste-oriented Approach)

The concept of Waste Minimisation Clubs (WMCs) is to exchange experiences related to the implementation of the waste minimisation procedure among its company members. It is proved that WMCs can encourage companies to improve their economic performance by reducing costs related to production of wastes. Approaches of WMCs should be based upon a process of training and involvement of several people from its member companies [Huisingh & Mebratu, 1998].

The first WMC in South Africa is the Metal Finishing WMC in the Durban region. This club was established by the Pollution Research Group of the University of Natal and the Water Research Commission (WRC) at the end of 1997. 30 metal finishing companies, with 5 to 200 employees, participate in this WMC. The main drivers for the companies to participate are the pressure of the local legislation and achieving costs savings by minimising wastes and emissions. The participants are all conducting a waste minimisation assessment. During official club meetings that are held every 3 months, the companies discuss the progress and results of their assessments [Kothuis, 1999]. In this way companies can learn from each others' ideas and mistakes. Workshops, seminars, presentations or company visits are organised between the official meetings. The topics of these events are chosen based on the interest of its members.

The Pollution Research Group is starting up a new WMC for the Hammarsdale region, also in the Durban area. Its members will include mostly medium sized enterprises. At present, 10 companies participate in this new club; among them are a textile and chemical company, a chicken abattoir and the sewage works. The members of this new WMC discharge their effluent water to the same sewage works. The driver of this WMC is to improve the quality of the discharges to the common sewage works, so the reduction of the water consumption and pollution shall have a very high priority during the waste minimisation assessment at the companies [Barclay & Kothuis, 1999]. Both WMCs in the Kwazulu-Natal province are funded by the Water Research Commission (WRC).

2.5.3.2 Waste Minimisation Club "Target Zero" in New Zealand (Waste-oriented Approach)

In August 1997, New Zealand officials initiated a major WMC project, called "Target Zero". It involves 25 companies in New Zealand. Each company is conducting the waste minimisation assessment. By regular written and oral reporting within the WMC, the potential to gain better results during the waste minimisation procedure is improved. Programme co-ordinators are working together with regional and local governmental officials and with leaders of chambers of commerce, trade unions, industries and universities to help ensure that the WMC "Target Zero" will become successful.

The project focuses upon product and process improvements, both within individual companies and across a group of companies. By adopting this focus the project will promote the implementation of the broader concepts of cleaner production, cleaner products and industrial ecology.

A unique feature is the analysis of external material flows of the involved companies as well. Once the companies have completed the waste minimisation assessment, the options for sharing and exchanging utilities, eg wastewater, solid waste and energy, between all involved companies are being explored as well. In other words, in the future members will be working on the establishment of "Industrial Ecology" networks to build upon the waste minimisation work being done within each company. This analysis of inter-company cleaner production will provide a baseline of what can practically be achieved by co-operating industry in New Zealand, and further develops the regional model for the development of cleaner production [Brown, 1997].

One important conclusion of the "Target Zero" project is that without proper project support, the enthusiasm within a WMC diminishes with time and that innovators are regarded as exceptions. Also according to Brown, the success of cleaner production initiatives can be measured by the extent to which changed attitudes and procedures are translated into on-going, continuous improvements.

2.5.3.3 The Skills Challenge Supply Chain Programme of "Groundwork Trust" in the United Kingdom (Actor-oriented Approach)

Groundwork Trust is a network of charitable trust in the United Kingdom that helps SMEs in improving their environmental performance. More than 40 local trusts have been set up and partnerships have been established with over 100 local authorities and a large number of companies and NGOs.

The mission of Groundwork Trust is "to bring about sustainable improvements, through partnerships, to the local environment and contribute to economic and social regeneration" [Groundwork Trust, 1998]. Groundwork Trust works in partnership with a wide range of business support agencies, big business, sponsors and regulators to solve the problems of the SME-sector which have generally proved impracticable using most common approaches.

One project of Groundwork Trust is the Skills Challenge Supply Chain Programme. This programme uses the power of supply chain pressure in order to improve the environmental performance of SMEs. The programme uses several large "champion" companies. These companies have made strong commitments to environmental good practice and have committed themselves through their policies or management systems to work with a small selection of each of their suppliers to improve their performance too. These large companies act as "environmental leaders" and urge 10 to 15 of their suppliers to attend the Skills Challenge course. The "champion" company organises environmental courses and seminars in conjunction with Groundwork Trust to show their suppliers that they are committed to the programme. During the courses a general introduction of the Skills Challenges Programme is given and subjects such as energy management, waste management and environmental management are covered. 31 Suppliers have attended the course and have been environmentally reviewed by specialists employed by Groundwork Trust. The majority of these suppliers would not have improved their environmental performance if they were not urged to do so by their clients. This programme is a good example of how the supply chain can be made greener. After joining the Skills Challenge Supply Chain Programme the suppliers feel that environment can be business and marketing opportunity and costs reduction can be achieved by applying cleaner production strategies.

The case-studies conducted by the Groundwork Trust show that engaging SMEs in environmental improvement is not easy. Much effort has to be invested in raising awareness among companies before they get committed to an action plan to reduce waste and emissions within their company. Once the SMEs start to apply environmental improvement practices, the potential benefits become clear in terms of costs savings, improved market performance, future prospects and reduced environmental risks.

2.5.3.4 *The "Kalundborg" Eco-industrial Park in Denmark (Region-oriented Approach)*

The most famous example of industrial symbiosis (exchange of by-products) can be found in Kalundborg, Denmark where the "industrial symbiosis" relationships grew spontaneously. What made Kalundborg so fertile for growing industrial symbiosis relationships is the city's environmental awareness as well as an ability to interact and work together. Industries are relatively non-competitive among themselves. Stricter environmental laws were forcing these industries to rethink how they must go about with their business [Lowe et al., 1997].

Kalundborg's Industrial Symbiosis, however, was not mapped out. One link after another began to fall neatly in place due to a combination of abiding by new pollution-control policies, cutting back on virgin energy and material inputs, and reducing escalating disposal costs, which all began to save the various companies money.

Kalundborg has four main industries: Asnaes Power Station, a coal-fired plant; Novo Nordisk, a maker of enzymes and pharmaceuticals; Gyproc, a plasterboard manufacturer; and Statoil, a refinery. The exchanges of wastes between the companies in Kalundborg are shown in Figure 2.8.

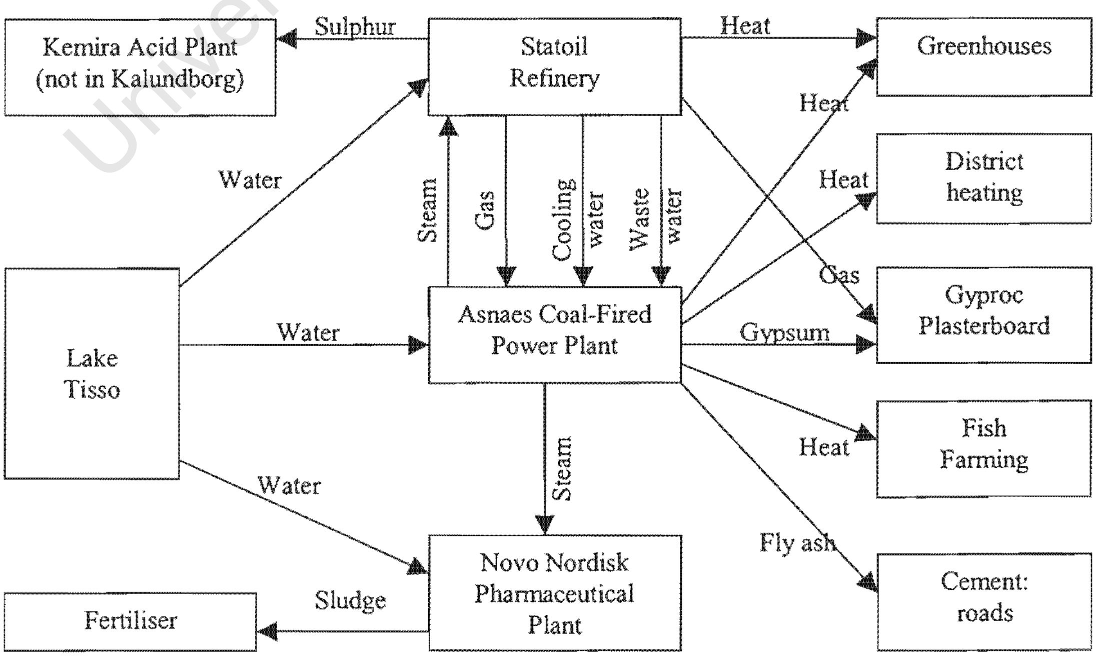


Figure 2.8 Exchange of Wastes in Kalundborg [Graedel and Allenby,1995]

The evaluation of the Kalundborg case-study showed that businesses, which want to have an industrial symbiosis relationship, must fit together. They have to have, more or less, the same culture and ideas about what to expect from each other. Besides this their production processes must make it possible to exchange by-products. Industrial symbiosis is not possible without the willingness to co-operate and trust between (potential) partners.

In Kalundborg regulations forced the industries to create technologies that were more efficient and environmentally benign. The environmental regulations and awareness in Northern Europe are generally regarded to be more developed than in the United States and far more so than in South Africa. Such regulations must encourage industries to be creative and innovative in finding eco-efficient solutions for their problems. Unfortunately, the enforcement of environmental legislation in South Africa is generall regarded as poor; although this is expected to improve in future. Other ways have to be found to motivate South African companies to be creative and innovative. This issue will have to be addressed by the industrial network approach.

Summarised, the learning points of Kalundburg's ecosystem are [Lowe et al. 1997]:
- All contacts have been negotiated on a bilateral basis.
- Arrangements must be commercially sound and profitable.
- Opportunities not within a company's core business, no matter how environmentally attractive, have not been acted upon.
- Each partner does its best to ensure that risks are minimised.
- Each company evaluates their own deals independently; there is no system-wide evaluation of performance, and they all seem to feel this would be difficult to achieve.
- A short physical distance between partners is necessary for economy of transportation (many transfers are not economically or technically feasible over long distances).
- Development must be voluntary, in close collaboration with regulatory agencies.

2.5.4 Drivers and Barriers for Networking of Businesses

As mentioned in previous subsections, it is stipulated that companies can realise environmental and economic benefits by working together as opposed to acting individually. This subsection discusses the drivers and barriers of a company to intensify or optimise its relationship with one or more of its network partners.

Drivers for network initiatives have to be addressed in order to encourage and initiate co-operative solutions for the improvement of the environmental performance of SMEs. Rosenthal [1999] identified nine areas in which networking of business could take place in an eco-industrial park. Within these areas, core drivers were identified for the establishment of networking initiatives. It is felt that most of these drivers can be applied to environmental networking initiatives in general and do not necessarily have to be related to eco-industrial parks. An overview of these areas and core drivers for environmental networking initiatives is shown in Table 2.5.

Areas in which environmental networking initiatives can occur	**Core drivers**
Materials	Shared buying
	Customer / supplier relations
	By-product connections
	Creating new material and product markets

Areas in which environmental networking initiatives can occur	Core drivers
Transportation	Shared transport
	Common vehicle maintenance
	Alternative packaging
Human resources	Human resource recruiting
	Joint benefit and wellness packages (health insurance etc.)
	Common needs (eg. maintenance)
	Training
	Flexible employee assignment
Information / communication systems	Internal communication systems
	External information exchange
	Monitoring systems
	Computer and software compatibility
	Joint management systems
Quality of life / community	Integrating work and recreation
	Co-operative education opportunities
	Volunteer and community programmes
	Involvement in regional planning
Energy	Green buildings
	Energy auditing
	Co-generation
	Spin-off energy firms
	Alternative fuels
Marketing	Green labelling (eco-labelling)
	Accessing "green" markets
	Joint promotions (eg. advertising)
	Joint ventures
	recruiting new companies
Environment, occupational health and Safety	Accident prevention
	Emergency response
	Cleaner production (eg. waste minimisation)
	Multimedia planning
	Design for environment (eco-design)
	Shared environmental information systems
	Joint regulatory permitting
Production process	Pollution prevention
	Scrap reduction and reuse
	Production design
	Common sub-contractors
	Technology sharing and integration

Table 2.5 Areas and Core Drivers for Networking Initiatives

Without addressing and overcoming "networking" barriers, it is unlikely that identified co-operative solutions for SMEs to improve their environmental performance will be implemented. According to Coleman [1994], Côté [1994], Lichtenstein & Hoeveler [1996] and Tang et al. [1998], the barriers for networking of businesses can be summarised as:

- There might be limited trust amongst network partners which does not encourage businesses to work together with each other *(trust)*.

- Network partners might compete in the same market which limits the willingness of a company to establish partnerships with its competitors, especially if the market conditions are tight *(competitiveness)*.
- There can be a possible conflict in commercial interests amongst network partners *(conflict in interests)*.
- Co-operative solutions may require a change of thinking or working methods; these changes concern cultural changes which are often hard to achieve *(change of culture)*.
- Certain co-operative solution might require the exchange of confidential information or trade-secrets *(confidentiality)*.
- There is a reluctance to depend on others, companies prefer to be fully in-control themselves *(dependency)*.
- There is a level of uncertainty involved as certain tasks are given out-of-hand *(uncertainty)*.

2.5.5 Success Criteria for Networking of Businesses

In order for external parties to successfully assist SMEs in improving their environmental performance, success criteria have to be met. Lichtenstein & Hoeveler [1996] mention in their work that the following three factors should be considered before initiating a networking programme:

- To be "do-able", collaboration between firms has to be based on mutual trust and co-operation among the participants of business network;
- To be successful, the business networks must have results which are directly linked to the specific needs of the all involved partners;
- To be sustainable, the benefits of the business network for the participants must be measurable to justify the time and financial investment.

According to Nesheim and Reve [1996], three phases can be distinguished for the establishment of networking initiatives. The first phase is one of developing relationships between (potential) partners. Secondly there is an organisational phase. The last phase is the implementation of joint actions. The results of the business network will only be there when all three phases have been successfully completed. Research of the business networks showed that many of them failed, but those that succeeded often achieved results which exceeded their most optimistic expectations.

Nesheim and Reve also state in their work that the establishment of an efficient and effective networking initiatives should be based on the following success criteria:

- The networking initiative should include a system or a mechanism which prevents the leakage of confidential information.
- The uncertainty or dependency factor should be kept as low as possible.
- The network initiative should be formalised in order to clarify the roles of all parties involved, and also to obtain commitment from all participants.
- The network initiatives should aimed at the ordinary business activities which have a high potential to gain economic benefits to all involved parties.
- The network initiative needs a facilitator who can co-ordinate the activities and involvement of the participants.

2.6 Further Concepts of Interest in the Identification of Eco-efficient Improvements in the Industrial Networks of SMEs

The central problem of this research project is the perceived limited potential for South African SMEs in the manufacturing sector to improve its environmental performance on their own.

Systems analysis and the methodology for a life cycle assessment are approaches which have a wider systems boundary, scope and focus area than the waste minimisation methodology. They are regarded as valuable concepts for the identification of co-operative solutions which should enable SMEs to improve their environmental performance with assistance from its business partners.

These two concepts are discussed in the following subsections.

2.6.1 Systems Analysis

The identification of eco-efficient improvement opportunities in the networks of SMEs is a rather complex problem; a systems approach can make a valuable contribution to the analysis of this complex web of organisations which are interacting with an SME.

A general definition of a system is a plan or scheme according to which things are connected into a whole. According to Jenkins [1969], the aim of systems thinking is to provide a method by which complex problems, activities and organisations can be analysed. One of the advantages of the systems approach is that it is possible to look at entirely different problems coming from different areas of technology and business.

2.6.1.1 Properties of a System

Jenkins summarised the properties of systems as follows:

1. A system is a complete grouping of human beings and machines.
2. Systems may be broken down into sub-systems, the amount of sub-system detail depending on the problem being studied. Flow-block diagrams provide a readily understood way of describing these sub-systems.
3. The outputs from a given sub-system provide the inputs for other sub-systems. Thus the performance of a given sub-system interacts with the performance of other sub-systems and hence can not be studied in isolation.
4. The systems being studied will usually form part of a hierarchy of such systems. The systems at the top are very important and exert considerable influence on the systems lower down.
5. To function at all, a system must have an objective, but this is influenced by the wider system of which it forms part. Usually, systems have multiple objectives which are in conflict with one another, so that an overall objective is required which effects a compromise between these conflicting objectives.
6. To function at maximum efficiency, a system must be designed in such a way that it is capable of achieving its overall objective in the best way possible.

In general, a sub-system may be regarded as some process which transforms certain input flows of money, materials, energy, information or decisions into corresponding outputs, as shown in Figure 2.9. The outputs from one sub-system thus provide the inputs for other sub-systems.

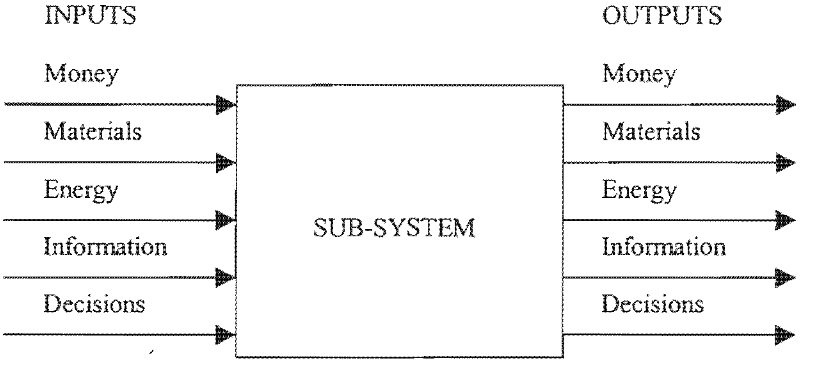


Figure 2.9 Example of a Sub-System [Jenkins, 1969]

2.6.1.2 *Systems Thinking and Sustainability*

Since the publication of the article "The Systems Approach" in the Journal of Systems Engineering written by Jenkins in 1969, the systems theory has developed and has been used to describe the sustainable society and the future industry-environment partnership by Wallner [1998].

An industrial system is always part of system at a higher hierarchical level, like a city of a region. The industrial system consists of a network of interacting businesses that are linked to each other. These businesses are the basic elements of the industrial system. Wallner refers to these basic elements as process units, but if the industrial system is seen as the "reference" system these basic elements or process units can be named sub-systems according to the work of Jenkins.

According to Wallner, sustainable or more efficient industrial systems can be created by increasing the complexity of the system. The complexity of an industrial system can be changed at all levels: local, regional, national, international and global level. There are three ways to increase the complexity of such a system in order to become sustainable:

- change the number of sub-systems (companies) in the industrial system;
- change the diversity of the sub-systems (type and size);
- change the interactions between sub-systems (connections and density).

Therefore, within the boundaries of the system, these three parameters should be optimised in order to increase the complexity and to improve the systems sustainability. The optimum network structure can not be specified in general terms, but rather depends on the specific conditions and characteristics of a system. The main success factors to create a sustainable industrial system (or improve the sustainability) are creativity and flexibility and not perfection and methodical inflexibility.

2.6.2 ***Life Cycle Assessment***

Another interesting tool for the analysis of the environmental performance of industrial systems or networks is the methodology for life cycle assessment. Life Cycle Assessment (LCA) is the process of evaluating the effects that a product has on the environment over the entire period of its life cycle, covering all processes incl. extraction and processing manufacture, transport and distribution, use, reuse and maintenance, recycling, and final disposal.

The analysis takes into account the entire life cycle of the product or function, LCA is a tool that supports environmental decision-making. It does not replace other tools but rather provides additional information for a specific application. Most tools that support environmental decision-making deal with one type of object only: environmental impact assessment deals with new facilities, and risk assessment with assessing the impacts of pollutants from a specific installation. The object of a LCA is also singular: the environmental consequences of a product or, more generally, of the function which the product is designed to perform.

The main constraint for an SME to conduct a LCA concerns the required time-investment. A possible way to decrease the time-investment is to reduce the level of detail of a LCA assessment. According to the work of Wenzel [1998] three levels of detail can be distinguished in conducting a LCA:

- A "full LCA" is based on the most complete qualitative and quantitative information that includes a new data inventory.
- A "screening-LCA" which only includes readily available data, a new data inventory is not done.
- A "matrix-LCA" (or abridged LCA) which includes qualitative and semi-quantitative information of the assessed process of product.

It is estimated that the time-investment for a matrix-LCA is 1 to 2 working days, for a screening-LCA 10 to 20 working days, while a full LCA requires more than 100 working days [Guld, 1998].

SMEs normally do not have the financial, time and knowledge resources to conduct a full LCA on their own. Therefore the ratio between the time invested and the LCA assessment results must be as favourable as possible. The choice of the level of detail also greatly depends on the purposes and goals of the LCA that is to be conducted.

If full support of the SME is required for the conduction of a LCA, the assessment must be simple and limited. Simple because the SMEs normally are not interested in academic discussion and have a need for an understandable and easy approach. Limited because the collection or creation of a lot of new data requires a significant amount of work and that is something an SME is usually not willing to wait for.. Based on these experiences, the best assessment method for an SME is a matrix-LCA.

2.7 Conclusions

The environmental performance of the South African manufacturing sector is poor, in particular amongst SMEs. SMEs lack the expertise, know-how and financial resources to improve their environmental performance on their own.

Waste minimisation is a valid and proven tool for the identification of ways to reduce or eliminate wastes. However, the systems boundaries, scope, and focus of the WM-methodology seem be too narrow to achieve the required environmental improvement of the South African manufacturing sector; a broader approach might be necessary.

Industrial ecology offers new opportunities to industry to improve its environmental performance. Instead of only addressing the internal flows of a company, as most environmental tools do (including the WM-methodology), industrial ecology also assesses the external flows. By extending the systems boundaries, additional environmental and economic benefits can be gained. The developed methodology to assess the industrial network of an SME can be seen as one of the approaches within industrial ecology.

Based on these observations, it can be concluded that there is a need for the development of a practical tool for SMEs which can identify eco-efficient improvements in its industrial network in which it operates naturally.

A review of the theory of industrial ecology and networking of businesses, as well as the practical application of these concepts in industry, provide important lessons for the development of a method for the identification of eco-efficient improvements in the industrial networks of SMEs. Some of the features which the developed methodology must have can be derived from the reviewed literature and experiences; which can be summarised as:

- the developed methodology must be simple and practical to apply;
- the industrial network methodology should aim to address and eliminate the barriers of industrial networking, and incorporate the drivers for networking initiatives (see Subsection 2.5.4);
- the identified improvements in the industrial network of an SME must be beneficial to and economically, technically and socially feasible for all parties involved in order to obtain commitment during the implementation phase;
- the facilitator plays a vital role in co-ordinating the experiments for testing the developed methodology.

Systems thinking and LCA are two valuable concepts for the method development. An industrial network, as defined in this research project, is a complex web of organisations connected by material, financial and information linkages. The theory of systems analysis can provide a framework by which the industrial network of an SME can be analysed. A matrix LCA seems to be a useful tool, which is simple enough to be applied by SMEs, for the identification of environmental constraints in the industrial network of an SME.

3 A Methodology for the Assessment of an Industrial Network

3.1 Introduction

This chapter describes the developed methodology for the identification of eco-efficient improvements in the industrial networks of SMEs. This methodology is referred as the industrial network assessment.

Section 2.2 applies the lessons from the literature review to the developed methodology in order to provide insight for the method development. The phases and a total overview of the developed methodology for the assessment of industrial networks are given in Sections 3.3 and 3.4 respectively. The purpose and a description of each step within the industrial network assessment procedure are then discussed in detail.

3.2 Lessons from the Literature Review

The four observations, which initiated this research project, were discussed in the literature review. The literature study revealed various valuable lessons for the development of the industrial network approach and its experiments. These lessons are applied to the proposed industrial network assessment.

3.2.1 Properties of the Proposed Industrial Network Assessment

In the literature review, the WM-methodology was evaluated on its systems boundaries, scope and main focus. This evaluation gave insight into the limitations of a methodology, which analyses an independent manufacturing entity, rather than analysing and optimising a complete industrial system. In this research project, an industrial system corresponds with the industrial network model, as discussed in the Introduction.

By knowing the limitations of the WM-methodology, the properties of the proposed industrial network assessment can be determined. These properties are discussed in the following subsections.

3.2.1.1 Systems Boundaries of Proposed Industrial Network Approach

As discussed in Section 2.5 "Opportunities Offered by Networking of Businesses" (Chapter 2), a company can improve its environmental and economic performance by utilising the opportunities of the network in which it participates naturally. In other words; instead of "only" analysing the sub-system, as done during a waste minimisation assessment, additional improvements may be identified if the complete system is taken into account. Figure 3.1 visualises how the five waste minimisation techniques can be applied on a complete system, in this research project an industrial network of an SME. This figure gives an indication of the increased opportunities by extending the systems boundaries of a waste minimisation assessment.

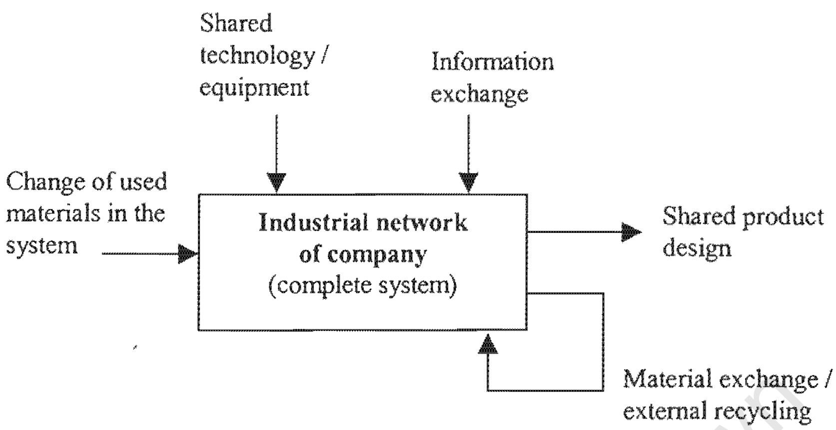


Figure 3.1 Systems Boundaries of the Proposed Industrial Network Approach

3.2.1.2 *Scope of the Proposed Industrial Network Approach*

Figure 3.2 shows to what extent the WM-methodology and the proposed industrial network assessment cover the strategies of the waste management hierarchy.

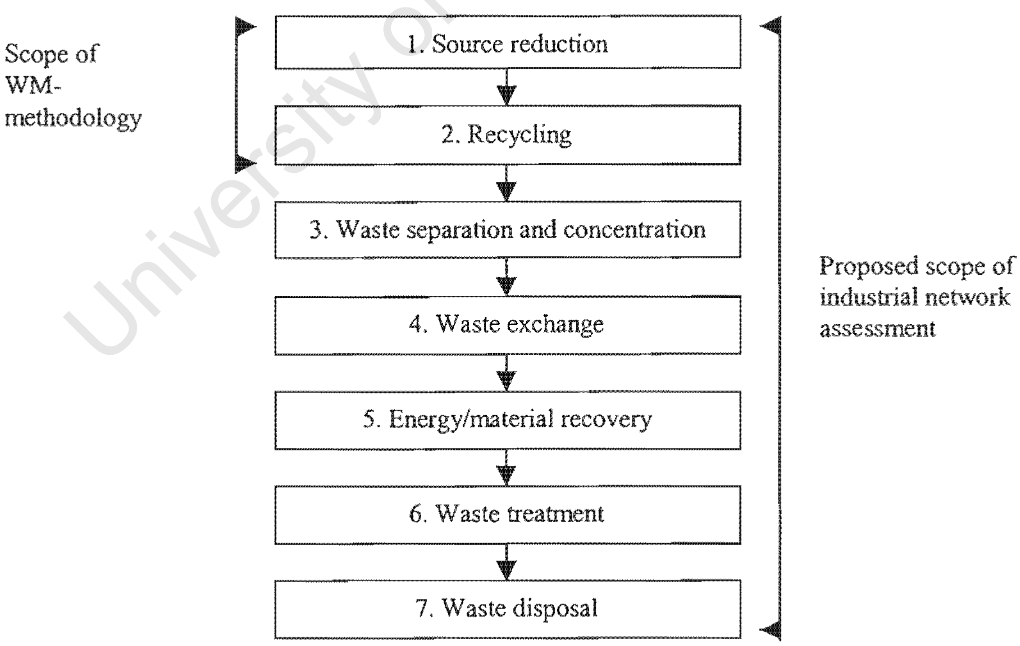


Figure 3.2 Proposed Scope of the Industrial Network Approach

The coverage of the waste minimisation assessment of "only" two categories, although the two most preferred ones, can be seen as a limitation of the application of the WM-methodology in South Africa. Options, which are not related to source reduction and internal recycling, will not be identified by the waste minimisation assessment. However, these options might still improve the environmental performance of a company significantly. For example, waste exchange between companies proves to be environmentally and economically feasible in the Kalundborg Ecosystem [Lowe et al., 1997].

In order to fully utilise the potential for environmental improvement of SMEs in the South African manufacturing sector, all waste management strategies should be incorporated in the industrial network approach, as shown in Figure 3.2. Obviously, preference should be given to options higher in the waste management hierarchy.

3.2.1.3 *Focus of the Proposed Industrial Network Approach*

The literature review showed that the main focus of the worksheets used during a waste minimisation assessment is on wastes directly associated with the company's production process and its waste treatment facilities. Figure 3.3 visualises the main focus of the WM-methodology and proposed focus of the industrial network assessment.

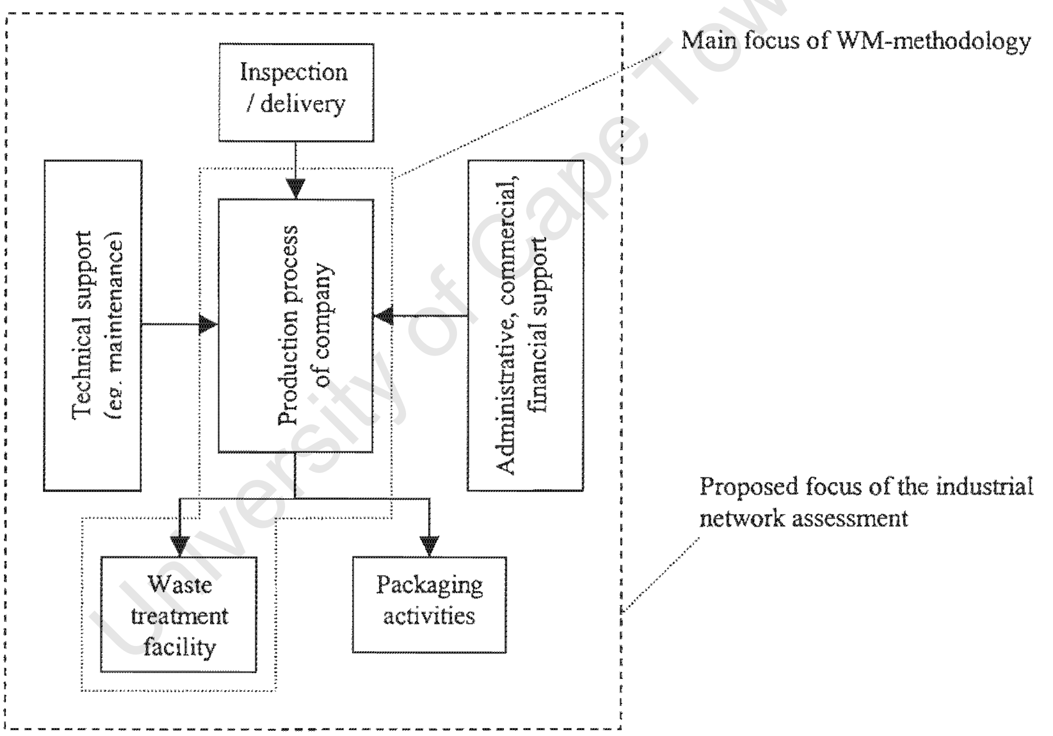


Figure 3.3 Proposed Focus of the Industrial Network Assessment

It is proposed that the industrial network approach should incorporate the evaluation of all business activities of an SME in order to fully utilise the company's potential to improve its environmental performance.

3.2.2 ***Drivers and Barriers for Co-operative Solutions in an Industrial Network***

An overview of areas and core drivers in which networking of businesses could take place in an eco-industrial park was discussed in the literature review [Rosenthal, 1999]. The original list of core drivers, as developed by Rosenthal, was adjusted in order to obtain a list of drivers for networking initiatives within an industrial network of a company. In Table 3.1, this updated list of core drives is linked with the network partners categories, as distinguished in the industrial network model, which could be involved to utilise the driver in question. The barriers for networking of businesses are also linked to the core drivers.

Drivers of co-operative initiatives within industrial network:	**Possible co-operative partners within industrial network:**	**Potential barriers:**
Materials		
Shared buying	competitors	competitiveness, confidentiality
Customer / supplier relations	competitors	competitiveness, confidentiality
By-product connections	suppliers, clients, competitors, support organisations, waste treatment companies	trust, change of culture, confidentiality, dependency, uncertainty
Creating new material and product markets	clients, competitors	competitiveness, confidentiality, trust
Transportation		
Shared transport	suppliers, clients, competitors, waste treatment companies	conflict of interest, change of culture, dependency
Common vehicle maintenance	suppliers, clients, competitors, maintenance companies	conflict of interest, trust
Alternative packaging	suppliers, clients	conflict of interest
Human resources		
Human resource recruiting	shareholders, competitors, support organisations	trust, competitiveness, conflict of interest, change of culture, confidentiality
Joint benefit and wellness packages (health insurance etc.)	shareholders, competitors, support organisations	conflict of interest
Training	suppliers, clients, competitors, support organisations	trust, competitiveness, conflict of interest
Flexible employee assignment	suppliers, clients, competitors, support organisations	trust, competitiveness, change of culture, dependency, uncertainty
Information / communication systems		
External information exchange	shareholders, suppliers, clients, support organisations, government	trust, change of culture, confidentiality
Monitoring systems	shareholders, suppliers, clients, support organisations	trust, change of culture, confidentiality
Computer and software compatibility	shareholders, suppliers, clients, support organisations	confidentiality, dependency
Joint management systems	shareholders, suppliers, clients, support organisations	trust, change of culture, confidentiality
Quality of life / community		
Integrating work and recreation	community organisations	trust, conflict of interest
Shared sponsoring	all network partners	trust, conflict of interest
Energy		
Energy exchange	support organisations, maintenance companies	trust, change of culture, dependency, uncertainty

Drivers of co-operative initiatives within industrial network:	**Possible co-operative partners within industrial network:**	**Potential barriers:**
Energy monitoring and auditing	suppliers, clients, competitors, support organisations, maintenance companies	change of culture, confidentiality
Marketing		
Green labelling (eco-labelling)	suppliers, clients, competitors, support organisations	competitiveness, conflict of interest, confidentiality
Accessing "green" markets	clients, competitors, support organisations	competitiveness, change of culture, confidentiality
Joint promotions (eg. advertising)	clients, competitors, support organisations	conflict of interest, change of culture, competitiveness
Joint ventures	suppliers, clients, competitors	trust, competitiveness, conflict of interest, dependency
Environment, health and safety		
Accident prevention	support organisations, government	trust
Emergency response	support organisations, government	trust
Cleaner production (eg. waste minimisation)	suppliers, clients, competitors, support organisations, government, waste treatment companies	conflict of interest, change of culture, confidentiality
Design for environment (eco-design)	suppliers, clients, support organisations, waste treatment companies	trust, conflict of interest, change of culture, confidentiality
Shared environmental information systems	suppliers, clients, support organisations, government	trust, change of culture, confidentiality
Production process		
Production process optimisation	suppliers, clients, competitors, support organisations, waste treatment companies	competitiveness, conflict of interest, change of culture, confidentiality
Shared sub-contractors	suppliers, clients, competitors	change of culture, dependency, uncertainty
Technology sharing and integration	suppliers, clients, competitors	trust, competitiveness, change of culture, confidentiality, dependency

Table 3.1 Drivers and Barriers for Improvements within Industrial Network Model

Table 3.1 reveals that there is potential for improvement within the industrial network of a company. It has to be mentioned that this table is based on the opinion and experience of the author of this thesis; the purpose of the table is just to give an indication of the improvement potential within the industrial network and the expected barriers.

The industrial network approach should incorporate the discussed drivers for networking of businesses and should provide a mechanism to overcome or eliminate the addressed barriers.

3.2.2.1 *Systems Analysis and the Industrial Network Approach*

As discussed in the literature review, a system can be defined as a plan or scheme to which things are connected into a whole. The definition of a system can be applied to the industrial network model of Kothuis and Petrie [1997]. The distinguished network sections within the industrial network model, for example production of raw materials and waste treatment companies, correspond with the properties of the sub-systems.

Jenkins [1969] has conducted extensive research on systems thinking and concluded that a system can be characterised by six generic properties. The properties of a system, as developed by Jenkins, can be applied to the industrial network model; these applied properties can be summarised as:

1. An industrial network is a grouping of linked companies / organisations. The links concern material, financial and information flows.
2. Industrial networks may be broken down into sub-systems, the amount of sub-system detail depending on the problem (identification of eco-efficient improvement opportunities) being studied. Flow-block diagrams provide a readily understood way of describing these industrial networks and their sub-systems.
3. The outputs from the sub-system in the centre of the industrial network, the SME, provide the inputs for other sub-systems. Thus the performance of a given sub-system interacts with the performances of other sub-systems and hence can not be studied in isolation.
4. The sub-systems within the industrial network being studied will in certain cases form part of a hierarchy of sub-systems, for example the winning of raw materials and the production of raw materials. The sub-systems in the beginning of the supply chain are very important and will have considerable influence on the environmental performance of the sub-systems lower down.
5. In order to function each sub-system must have an objective, but this is influenced by the wider industrial network of which each sub-system forms part. Usually, industrial networks have multiple objectives, which are in conflict with one another, so that an overall objective is required which effects a compromise between these conflicting objectives.
6. To function at maximum efficiency, an industrial network must be designed or changed in such a way that it is capable of achieving its overall objective in the best way possible.

If the theory of Wallner [1998], as discussed in the literature review, is applied to the industrial network model, then there are three ways to increase the complexity of the industrial network of an SME in order to make it more efficient:

- change the number of business partners in the industrial network;
- change the diversity of network partners in the industrial network;
- change the interactions (connections and intensity of the material, financial and information flows) between SMEs and its network partners.

So within the boundaries of the system, these three parameters should be optimised in order to increase the complexity and therefore improve the efficiency of the industrial network as well.

3.2.3 Life Cycle Assessment and the Industrial Network Approach

The aim of this Masters research project is the identification of eco-efficient improvements within the industrial network of an SMEs. A way to identify these improvements is starting with the analysis of the environmental constraints in the industrial network.

As discussed in the literature review (Chapter 2), LCA can be used to study the environmental impact of either a product or the function of a product. It is believed that LCA can make a valuable contribution to address environmental constraints in an industrial network.

Of the three possible levels of detail for LCAs, the matrix-LCA method seems to be the most appropriate tool for this research project as this project focuses on SMEs. However, the framework of matrix-LCA has to be adjusted in order to make suitable for its "new" purpose. The adjusted matrix LCA, which is named "network impact matrix", will be discussed in Subsection 3.7.2.2 as it is part of the assessment phase of the developed industrial network approach.

3.3 Phases of the Proposed Industrial Network Assessment

The proposed industrial network assessment consists of four phases; viz. the inventory phase, the assessment phase, the discussion / selection phase and the feasibility phase, as shown in Figure 3.4.

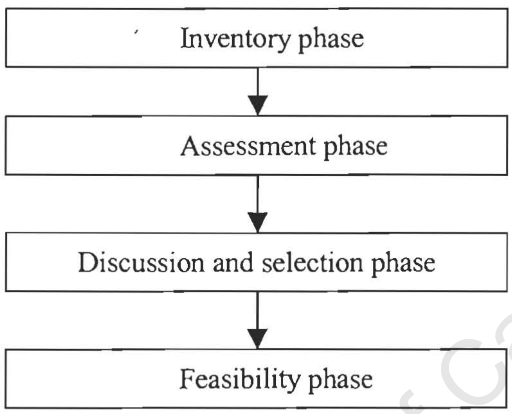


Figure 3.4 Four Phases of the Industrial Network Assessment

During the inventory phase, information on the structure and functioning of the company's industrial network is gathered, including the visualisation of the industrial network. Improvement options within the industrial network are sought in the assessment phase. These identified improvement options have to be discussed and the options with the highest potential to be successful have to be selected. The last phase consists of a feasibility analysis on the selected improvement options.

3.4 Proposed Procedure of an Industrial Network Assessment

Figure 3.5 shows the proposed procedure for an industrial network assessment. Each step within this procedure will be discussed in the following sections.

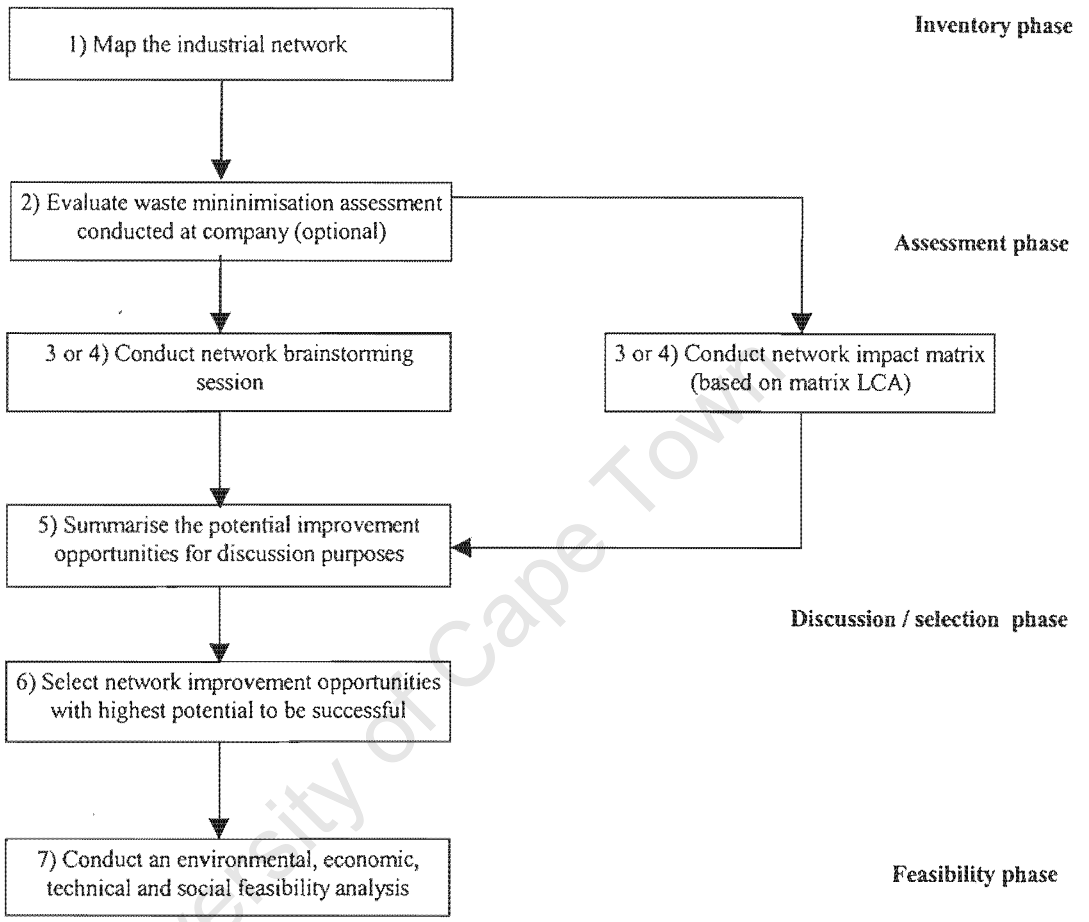


Figure 3.5 Flow Diagram for Industrial Network Assessment

3.5 Step 1: Map the Industrial Network

3.5.1 Purpose

An industrial network can be defined as a web of organisations connected, directly or indirectly, by material, financial and/or information flows with different magnitudes. An industrial network is mapped around a specific company. This means that each mapped industrial network is unique in terms of structure and relationships between network partners.

Without insight into the structure and working of the network around a company it will be difficult to identify improvement options within this industrial network. Identifying improvements always starts with analysing the matter of concern, in this case the industrial network of an SME.

The purpose of the network mapping is to get an overview of what is happening "around" the company in terms of material, financial and information flows in order to identify eco-efficient improvements within the industrial networks of SMEs.

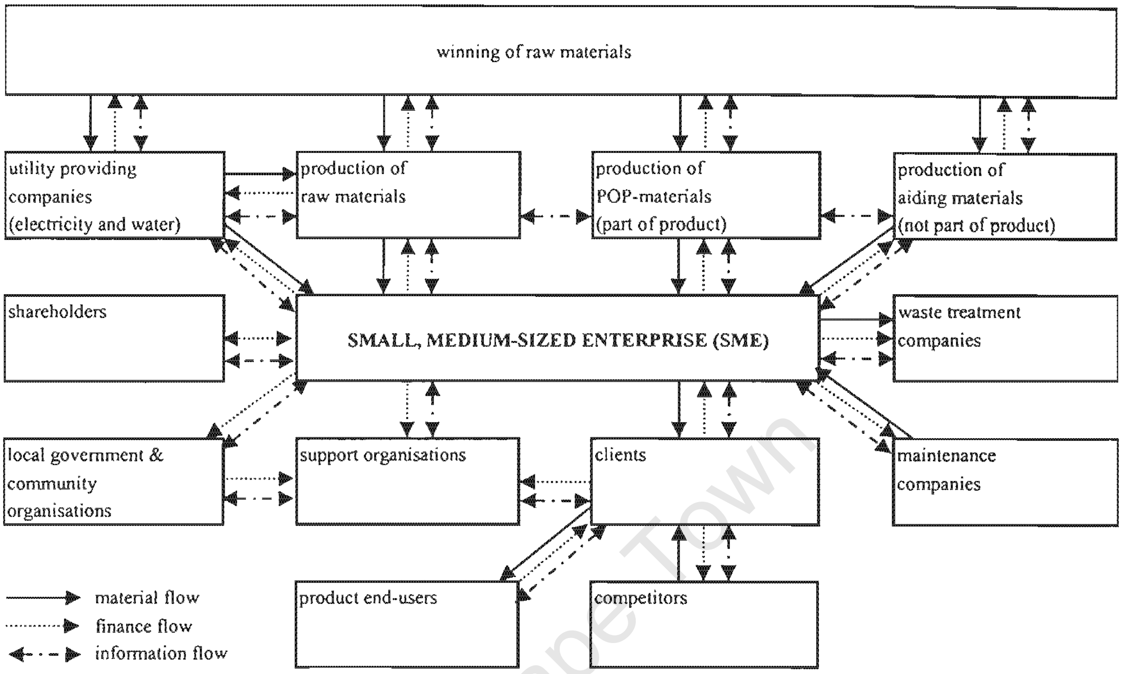


Figure 3.6 Industrial Network Model of an SME [Kothuis & Petrie, 1997]

The mapping of the industrial network is based on the model shown in Figure 3.6. The material, financial and information linkages between the SME and its partners are visualised in network maps by different types of arrows. The above figure also shows the different sections of network partners, which are distinguished during the network mapping. The SME can always be seen in the center of its own network.

3.5.2 **Description**

Figure 3.7 gives an overview of a procedure for the mapping of an industrial network. The steps are numbered from 1a to 1f as the network mapping constitutes the first step of the industrial network assessment.

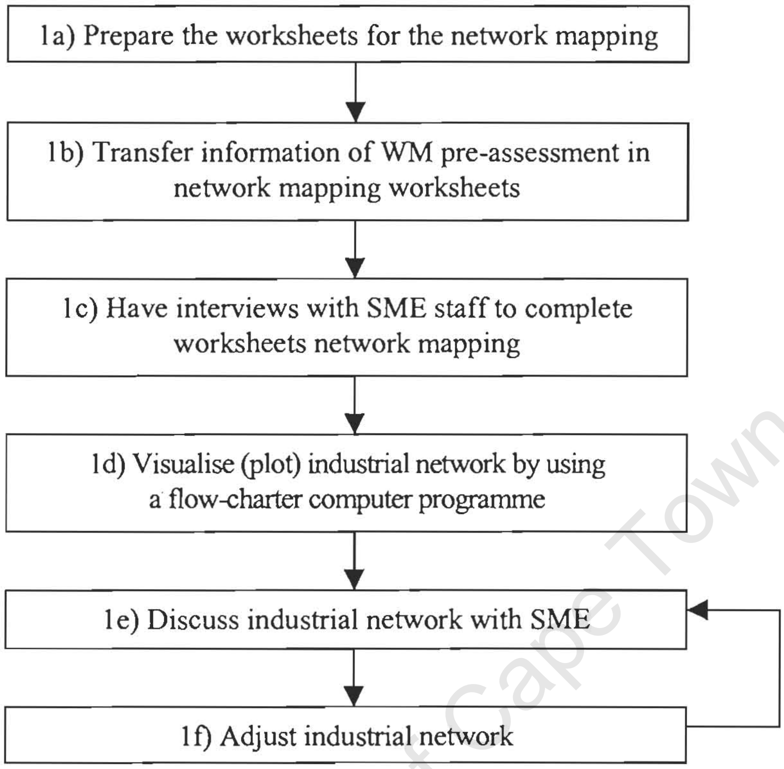


Figure 3.7 Procedure for the Mapping of an Industrial Network

Step 1a: prepare the worksheets for the network mapping

To gather the network information as efficiently as possible, worksheets have been developed for each network section. The worksheets can be adjusted according to particular characteristics or needs of the company. Appendix A includes the framework of the worksheets, which were used for the mapping of the company's network.

Step 1b: transfer information of WM pre-assessment in network mapping worksheets

At companies where a waste minimisation assessment is conducted, a pre-assessment report is made in order to select priority areas to focus on during the waste minimisation assessment phase. All the information of the pre-assessment report, which is valuable for the mapping for the SME's industrial network, has to be transferred into the network mapping worksheets. This will make the interviews more efficient as the information will only be gathered once.

Step 1c: have interviews with SME staff to complete worksheets network mapping

Interviews are held with the company staff to complete the network mapping worksheets. Depending on the network section, the interviewees are chosen. The worksheets are used as a guideline during the interviews.

Step 1d: visualise (plot) industrial network by using a flow-charter computer programme

The completed worksheets contain the relevant information to map the industrial network around the company. The industrial network is visualised with computer software (Micrografx Flowcharter) and is plotted in color on A1-paper size.

Step 1e: discuss industrial network with SME

Not all the required information to map the industrial network can be covered by the worksheets. The draft of the industrial network still needs to be discussed with the company staff to get their opinion on the mapped network.

Step 1f: adjust industrial network

According to the findings of the discussion, the draft industrial network has to be adjusted. Another discussion with the SME staff might be necessary, depending on the complexity of the network's structure.

3.6 Step 2: Evaluate the Waste Minimisation Assessment Conducted at the Company

3.6.1 Purpose

As it is stipulated that the industrial network assessment can generate improvement options additional to a waste minimisation assessment, it is necessary to gain insight into which feasible and non-feasible options were identified by the waste minimisation assessment. Feasible options already addressed and investigated by a waste minimisation assessment do not warrant further attention during the industrial network assessment. Non-feasible waste minimisation options can perhaps be made feasible if network partners of the company get more involved.

3.6.2 Description

Table 3.2 shows the framework for the evaluation of the waste minimisation assessment conducted prior to the industrial network assessment. Each identified waste minimisation option is assessed on environmental, economic and technical feasibility. A category "Other" is included as well. Based on the assessment of the evaluation criteria, it can be determined whether a wm-option is feasible or not. The last column states whether the feasible options were implemented by the company.

WM-option	Environmental effect	Economic feasibility	Technical feasibility	Other	Proven feasible?	Implemented?

Table 3.2 Evaluation of Waste Minimisation Assessment

3.7 Step 3 and/or 4: Network Brainstorming Session and Network Impact Matrix

3.7.1 Purpose

There are two methods to generate potential improvements within the industrial network, namely the network brainstorming session and the network impact matrix. These two steps in the exercise can be done separately and do not depend on each other. To what extent the two steps will generate similar or dissimilar results will result from the experiments conducted on the two case-study companies, as described in Chapter 4 and 5.

3.7.2 Description

3.7.2.1 Brainstorming Session

One technique to identify potential network improvements is to conduct a network brainstorming session, which is done with company staff of the SME. An industrial ecology checklist is used as a guideline during the discussion. This checklist is an abridged version of the checklists set up by Graedel & Allenby [1995] and DeSimone & Popoff [1997]. The brainstorming session relies on the company staff's experience and their knowledge of the industrial network. It is important to create an open atmosphere so that as many potential network improvements as possible can be generated.

Table 3.3 shows the framework of the checklist which is used during the brainstorming session with the staff members. The complete checklist can be found in Appendix B.

Ref. no.	CHECKLIST OF BRAINSTORMING SESSION	
1.	**Energy**	**Comments**
1.X	Check questions	
2.	**Environmental management**	**Comments**
2.X	Check questions	
3.	**Inspection / maintenance**	**Comments**
3.X	Check questions	
4.	**Packaging**	**Comments**
4.X	Check questions	
5.	**Process optimisation**	**Comments**
5.X	Check questions	
6.	**Product design**	**Comments**
6.X	Check questions	
7.	**Transport**	**Comments**
7.X	Check questions	
8.	**Wastes**	**Comments**
8.X	Check questions	

Table 3.3 Framework for the Brainstorming Checklist

3.7.2.2 Network Impact Matrix

The second technique to generate potential network improvements is to conduct a network impact matrix. The network impact matrix is based on the matrix LCA as described by Graedel [1998]. The goal of the network impact matrix is the identification of environmental constraints within the industrial network. Once the network constraints have been identified, possible ways to eliminate these constraints can be sought through a pro-active partnership approach.

Table 3.4 shows the framework of the network impact matrix. Instead of the life-cycle phases, the different phases within the industrial network are given. The developed worksheets to conduct a network impact matrix are included in Appendix C.

Network Impact Matrix	Environmental concerns					
	Material choice*	**Energy use***	**Solid residues***	**Liquid residues***	**Gaseous residues***	**Total**
Network sections:						
Pre-manufacturing	0 – 4	0 – 4	0 – 4	0 – 4	0 - 4	Sum/20
Product manufacturing by company	0 – 4	0 - 4	0 - 4	0 – 4	0 - 4	Sum/20
Product packaging and transport (to & from company)	0 - 4	0 - 4	0 - 4	0 – 4	0 - 4	Sum/20
Product handling by 1st, 2nd, 3rd tier clients	0 - 4	0 - 4	0 - 4	0 – 4	0 - 4	Sum/20
Waste processing by recycling / waste treatment companies	0 - 4	0 - 4	0 - 4	0 – 4	0 - 4	Sum/20
Total score	Sum/20	Sum/20	Sum/20	Sum/20	Sum/20	Sum/100

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)

Table 3.4 Framework for the Network Impact Matrix (after Graedel [1998])

Experiences, as discussed in the literature review, indicate that a full quantitative LCA is not feasible for SMEs due to the lack of time, knowledge and finance [Guld, 1998]. However, the abridged LCA method described by Graedel [1998] works with subjective ratings for the various environmental concerns (material choice, energy use, solid residues, liquid residues and gaseous residues) and can be done with much less time and financial investment. As the ratings of the environmental concerns are subjective, it is important to discuss the network impact matrix with various industry and LCA specialists and to consult available literature. This will prevent ratings from being incorrectly interpreted and/or certain network improvements being unidentified. The scoring guidelines and protocols for an abridged life cycle assessment, as described in Graedel's work, can provide assistance for assessing the environmental concerns for each life cycle stage or network section. These guidelines are included in Appendix D.

The network impact matrix will largely be based on information gathered during step 1 of the developed procedure for the industrial network assessment, the mapping of the industrial network, and readily available data from other external resources.

3.8 Step 5: Summarise the Potential Improvement Opportunities

3.8.1 Purpose

The network brainstorming session and network impact matrix will identify potential network improvements. To streamline the discussions with staff members, the results of these two techniques have to be summarised as managers of SMEs often have a time-constraint. Their time should therefore be used as efficient and effective as possible. It is not feasible, time-wise, to discuss the findings of the brainstorming session and network impact matrix in great detail.

3.8.2 Description

Table 3.5 shows the framework of the summary of the identified improvement options. This summary should provide enough information to the staff members for the selection of options for which a detailed feasibility analysis is required.

Potential improvement option	**Option characteristics**	**Action plan**	**Potential network partners to work together with**	**Identified by WM-assessment?**	**Select option for detailed feasibility analysis?**

Table 3.5 Framework for the Summary of the Identified Improvement Options

The identified improvement options are classified as an internal or an external improvement. An internal improvement is defined as an improvement, which "only" has an economic, technical and social impact within the company's physical boundaries. An external option has an economic, technical and social impact outside the company's boundaries as well. The environmental impact is, per definition, outside the company's physical boundaries.

The column "Option characteristics" evaluates who will benefit from the option and states if the option is an internal or external improvement.

The proposed actions to implement an option are given in the third column; this plan will give insight into the required time-investment to make an option successful.

The implementation of certain options may require the co-operation from network partners; which partners should or could get involved during the implementation is outlined in the fourth column.

If an industrial network assessment is conducted in addition to a waste minimisation assessment, some options might have already been identified by the waste minimisation assessment. It has to be decided if these options need further attention or a follow-up.

The last column is used to indicate whether an option is selected for a detailed feasibility analysis or not. This decision is made during step 6 of the industrial network assessment procedure.

3.9 Step 6: Select Improvement Opportunities

3.9.1 Purpose

Based on the results of step 5, a summary of the potential network improvement opportunities, a selection has to be made of options which have the highest potential of success and are most valuable for further investigation.

3.9.2 Description

The selection will be made during a discussion meeting, attended by company staff and the facilitator(s) of the industrial network assessment.

This step must not be confused with the feasibility analysis. It does not make sense to conduct a full feasibility analysis for all the potential network improvements. A first screening of the potential network improvement opportunities will prevent the waste of effort, money and time.

3.10 Step 7: Conduct an Environmental, Economical, Technical and Social Feasibility Analysis

3.10.1 Purpose

An improvement option will only be implemented if the option is considered feasible. The feasibility analysis focuses on four main issues, e.g.: environmental, economic, technical and social aspects.

The industrial network assessment aims to identify improvement options inside and outside the company's physical boundaries (internal and external improvement options).

The structure of the feasibility analysis on internal improvement options identified by the industrial network assessment corresponds with the feasibility analysis in a waste minimisation assessment [Berkel, 1996].

The external improvement options also require, besides a "normal" feasibility analysis, the consideration of external aspects. The following external aspects have to be addressed:

- Which network partners can or have to co-operate and to what extent?
- Get commitment from all involved network partners.
- What will the allocation of tasks be amongst the network partners?
- Determine costs and profit sharing amongst involved network partners.

3.10.2 Description

Table 3.6 shows the framework for the feasibility analysis of the selected improvement options. For each improvement option, a separate table should be completed.

Selected improvement option	**Environmental assessment**		**Economic assessment, considerations**	**Technical assessment, considerations**	**Social assessment, considerations**
	Eco-efficiency dimension	**score* A/B/C**			
	Material intensity				
	Energy intensity				
	Toxic dispersion				
	Material recyclability				
	Sustainable use of renewable resources				
	Product durability				
	Service intensity				
	Remarks:				

* *Rating of eco-efficiency key-dimensions:*
A = significant increase in performance per functional unit
B = no (significant) increase / decrease in performance per functional unit
C = significant decrease in performance per functional unit

Table 3.6 Framework for Feasibility Analysis of Selected Improvement Options

The World Business Council on Sustainable Development (WBCSD) has identified seven success factors for eco-efficiency [DeSimone & Popoff, 1997]. An improvement opportunity is considered to be environmentally feasible if the overall rating of these seven key-dimensions of eco-efficiency improves significantly within the industrial network. As indicated in Table 3.6, each key-dimension of eco-efficiency is rated according to three subjective categories. It is not considered viable, time-wise, to conduct a detailed environmental feasibility study on all improvement options.

An improvement opportunity is considered to be economically feasible if the simple payback period of the required investments does not exceed three years for any of the involved network partners.

The framework for the technical feasibility study depends on the type and characteristics of the improvement option. The following criteria will be, at least, taken into account:

- What the availability of required technology in South Africa?
- Was the technology developed recently or has the technology already proven itself?
- What is the required skill-level of the employees who have to work with the equipment?
- Does the supplier of the technology also provide good service during and after installation of the equipment?

A social feasibility study assesses the expected barriers and opportunities related to the willingness and motivation of the SME and its involved network partners to co-operate during the implementation phase of the identified improvements within the industrial network.

3.11 Closing

The purpose of this chapter was to provide a good understanding of the developed methodology for the assessment of an industrial network.

The conducted literature study, as described in Chapter 2, revealed that no methodologies or frameworks currently exist for the identification of eco-efficient improvement opportunities in the industrial networks of individual companies. It is hoped that the developed methodology, as described in this chapter, can provide such a framework, which is practical, effective and efficient enough to be applied on SMEs. If the developed methodology is proven unsuccessful, it may lay the foundation for future research.

The identified network improvements must always benefit the SME on which the industrial network assessment is carried out. The ideal situation is, of course, to identify network improvements which are beneficial for both the SME and its network partners because only then is there an incentive for all participants to make the improvement option work. It is not the aim of this method to identify network improvements, which only benefit the network partner(s) and not the SME.

Chapter 4 and 5 describe and evaluate the application of the industrial network assessment at respectively a medium-sized textile enterprise and a small-sized metal finishing company.

4 Application of the Method to a Medium Enterprise in the Textile Sector

4.1 Introduction

This chapter describes and evaluates the results of the application of the industrial network assessment at a company in the textile sector between May and September 1999.

A textile printing company participating in the research project "An Industrial Symbiosis View of SMEs" was selected for testing the developed industrial network assessment for the first time.

According to the SME-definition given in the introduction (Chapter 1), the textile printing company can be classified as a medium-sized enterprise. The company meets all quantitative (total annual turnover, total asset value and number of employees) criteria of a medium-sized enterprise. The company also meets the qualitative criteria of an SME.

The textile company did not complete a full waste minimisation assessment before the industrial network approach was tested. For this reason, it is not possible to evaluate the results and experiences of the industrial network assessment against a conducted waste minimisation assessment. However, a waste minimisation pre-assessment report had been compiled for the company; also a water savings project was carried out before the industrial network assessment was started.

During the experimental work with the textile printing company, the network impact matrix was conducted after completion of the network brainstorming session. At the metal finishing company (described in Chapter 5), the network impact matrix was completed first. The optimum sequence of these two techniques will be discussed in detail in Chapter 7 "Discussion and Conclusions".

In order to understand the terminology used in this chapter and the results of the experiment, a general overview of the South African textile industry and the textile printing company, respectively, is given in the following two sections. After this general overview, the results of the industrial network assessment at the textile printing company are discussed.

4.2 The South African Textile Industry

4.2.1 A Brief Description of the Textile Processes

Activities in the textile sector include the processing of wool and cotton and the manufacturing of textile products, including yarns and woven cloths. The production process in the textile industry can be divided into different stages.

The textile industry in South Africa can be segmented into the following major sectors:
- Fibre production
- Spinning
- Weaving
- Knitting
- Non-wovens
- Carpet production
- Fabric coating

The main fibres used in this industry are wool, cotton and synthetic fibres. Cotton is the most used fibre, wool and synthetic fibres are approximately equally used. Polyester is the most common synthetic fibre [EMG, 1993]. The processing stages of wool, cotton and synthetic fibres are displayed in Table 4.1. A detailed description of the different stages is provided in the glossary of this thesis.

Wool	Cotton	Synthetic
Scouring	Carding	Weaving or knitting
Carding	Spinning	Scouring
Spinning	Sizing	Dyeing
Knitting or weaving	Weaving	Scouring and bleaching
Wet scouring	Desizing	Finishing
Fulling	Scouring	
Washing	Mercerising and caustic recovery	
Bleaching and rinsing	Bleaching and washing	
Dyeing, printing and finishing	Dyeing or printing	
	Finishing and drying	

Table 4.1 Involved Stages of Wool, Cotton and Synthetic Fibre Processing [Barclay, 1996]

Companies in the textile industry include both large scale milling and treatment companies and SMEs. The large scale facilities have continuous and automated operating systems and the SMEs use batch and manual modes of operation. The advantage of SMEs is that they have the flexibility to process variable bathes or amounts of fabrics and garments on a contract basis and are better able to meet the specific requirements of clients..

4.2.2 Environmental Aspects of Textile Processes [EMG, 1993]

Wet-finishing processes to treat woven yarns and fabrics cause the most significant environmental impacts of the textile industry. Large amounts of water and various kinds of dyes and chemicals are used and discharged as liquid waste during the wet-finishing processes. Hence the critical problems are identified as:

- water consumption; and
- waste generated as highly contaminated aqueous effluent and sludge wastes.

Rinsing operations are responsible for a significant amount of the water consumption in the textile industry. Rinsing is necessary to remove process chemicals between the various process stages. Without rinsing, process chemicals will have a negative effect on the subsequent process steps; viz. reduced efficiency and effectiveness and poor product quality.

The effluent of wet-finishing processes often requires a wastewater facility to treat the natural impurities derived from the fibre and the process chemicals (mainly from rinsing processes) discharged to the sewer. The effluent can contain a.o. organic compounds, dissolved organic salts, sulphates, dyes and heavy metals. Most SMEs can not afford a wastewater treatment plant due to the high investment and maintenance costs. However, a treatment facility does not eliminate the environmental impacts of the effluent. The treatment facility will generate sludge containing heavy metals and inorganic salts. In South Africa, this sludge is mainly disposed on landfill sites.

Hazardous gaseous emissions, mainly volatile organics, are generated during bleaching operations and from drying operations for printed fabrics.

The textile industry also generates significant amounts of packaging. Although the packaging is not considered as a hazardous waste, it is certainly a matter of concern because of the large amounts. The bulk of this waste is not recycled or reused in South Africa, but ends up on landfill sites as well. This is unfortunate as most packaging waste has a great potential to be reduced, reused or recycled in a cost-effective way.

4.2.3 Support Organisations in the South African Textile Industry

Appendix E includes an institutional framework for the South African textile industry; it briefly summarises the services offered by each support organisation. The framework gives an indication of organisations that can assist SMEs within the textile sector in improving their environmental and economic performance.

The following organisations are included in this overview:
- CSIR – Division of Textiles (Textek)
- Department of Trade and Industry – Directorate: Textile, Clothing and Footwear (TCF)
- Textile Federation (Texfed)
- Textile Institute (TI)
- Clothing Federation
- Clotex
- Textile Training Board
- South African Cotton Textiles Process Employer Organisation (SACTPEA)
- South African Clothing and Textile Workers Union (SACTWU)
- South African Dyers and Finishers Association (SADFA)

4.2.4 A Brief Economic Review of the South African Textile Industry [Naumann, 2000a]

The textile industry is responsible for a notable contribution to South Africa's gross domestic product (GDP); 2% of the GDP is generated by textile production and sales.

It is estimated that 74% of South African textile companies are Small, Medium and Micro Enterprises (SMMEs). The government will increase its support (financial and other) to SMMEs as these companies are important for employment creation in the textile sector and its related upstream and downstream business partners.

The textile industry is currently under pressure, due to the globalisation of trade and the increased external access to the local market. The local industry in particular does not utilise the market opportunities offered by the globalisation of the economy and trade. The globalisation of trade challenges South Africa in a number of ways; viz. in terms of illegal imports, international agreements, cost of capital, productivity and input price developments.

The sector provides a significant number of direct and indirect employment opportunities. However, the textile employment numbers have decreased from approximately 100,000 direct employees in 1990 to about 63,500 employees in 1999. This is a decrease of almost 35%, the indirect employment figures not included. This decrease can be largely explained by the restructuring of the textile sector. Labour in the textile sector is regarded as unproductive and not internationally competitive, mainly due to the high percentage of low skilled workers in textile production.

For the last 10 years, the import and export of textile products have increased, although the exports have grown at a greater rate than the imports. The development of the exchange rate of the South African Rand against foreign currency (e.g. European countries and USA) favours the marketability of South African textile products and reduces the effects of the low manufacturing productivity. However, the high interest rates of the last decade had a significant negative effect on financial feasibility of investments in the South African textile industry. During 1999 and 2000, however, the interest rates were reduced which will have a positive effect on the industry on the medium and long term.

4.3 Description of Textile Printing Company

4.3.1 General Information

The core business of the textile company is the commissioned printing of textiles for primarily local clients. The company in this case study prints mainly on fabric which is used for underwear, sleepwear, children wear, active wear and outer wear. 80% of the printed fabrics are made of cotton; cotton/polyester blends and synthetic fabric material account for 15% and 5% of the printed products, respectively.

Approximately 115 people are employed by the textile company, of which 7 are management staff. The company produces 24 hours per day for 287 days a year, and processes over 5 million m^2 of fabric per year.

The company applies both the flatscreen and the rotary printing techniques which are practiced at two separate plants. The flatscreen printing technique is more suitable for the printing of small production runs and for textile products with an "artistic" look. The features of the rotary printing techniques make it ideal for the printing of large runs and patterns which require high definition and extra registrations.

The rotary plant currently accounts for 92% of the total production and 94% of the total water consumption. On average, the production costs per square meter printed fabric is higher for the flatscreen printing technique than for the rotary printing process.

The company's competitors are other commissioned printers as well as textile mills which have the capacity to both produce and print the textiles. Although the competition is increasing, the company has achieved consistent growth in previous years. The deployment of advanced technology and a "service oriented" relationship with their customers give the company a competitive advantage.

The company has close relationships with a few, carefully selected suppliers which provide the company with, besides the supplied product, technical support and assistance.

4.3.2 Production Process

Flatscreen versus rotary printing

The textile company applies both a rotary and flatscreen printing process. The main difference between these printing techniques is that with rotary printing the design is engraved onto a nickel hollow screen and with flatscreen printing the design is applied on a polymer flat screen. The roller permits continuous printing (higher printing speed possible) as well as improved registration. The difference between these two printing techniques is illustrated in Figure 4.1.

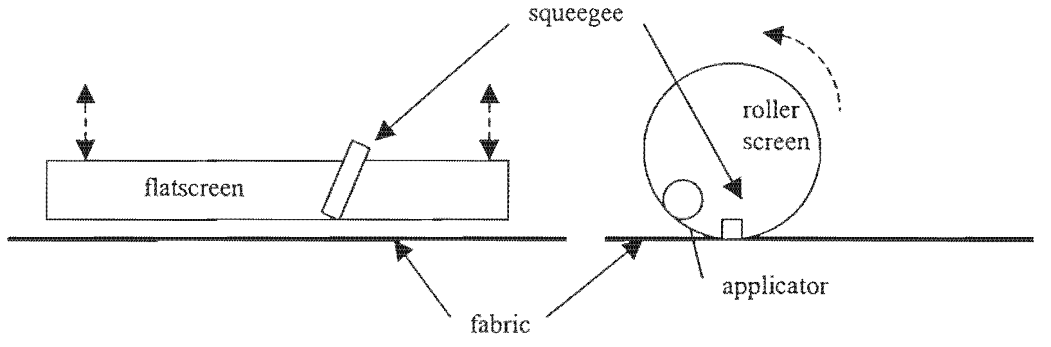


Figure 4.1 Difference between Flatscreen and Rotary Printing Technique

Process Phases

The industrial network assessment was conducted at the rotary plant of the textile printing company. The flatscreen plant was not included in the experiments as the it only accounts for 8% of the total annual production and 6% of the water in-take. Time-constraints also played part in the decision to exclude the flatscreen plant in the experiments. For this reason, only the rotary printing process is discussed in detail in this subsection. Figure 4.2 shows the three process stages of the rotary plant at the textile printing company. Each stage incorporates various process steps.

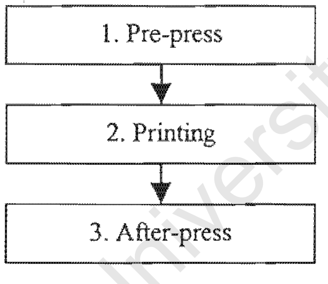


Figure 4.2 Process Stages of the Textile Printing Company

Pre-press

The pre-press stage incorporates all process steps before the actual printing of the fabric.

Based on the requirements of the clients, a coloured paste is formulated and made by the automatic colour kitchen. This machine mixes all the paste components (eg. hardener, softener, thickener, binder) with the pigments in order to get the correct coloured pastes for the print job. The coloured paste is the substance that will be applied on the fabric by the rotary printing machines. To make the coloured paste pure, it is filtered by squeezing it through a metal gaze.

The rotary screens need to be prepared for printing. An external company coats the rotary screens with a photo-sensitive emulsion and engraves the design in the emulsion by exposing the emulsion to ultra-violet light. The screens are returned and assembled at the printing company. During assembly the engraved screens are checked and touched-up by hand, metal rings are glued to the screens so that they can fit and register the screens in the printing machines.

Printing

The screens can then be installed in the rotary printing machine. For each printing colour, a different screen has to be installed in order to print the required design on the fabric. All screens are placed in series in the printing machine.

A rotating rubber blanket, on which is glue is applied, is used to transport the fabric through the printing machine. Once the fabric has been printed, it is left to air dry.

After-press

After air drying , the quality of the print and the fabric is checked. If necessary, the printed fabric is touched-up by hand.

The fabric is then led through a curing machine, a gas-heated oven, where the fixation process of the coloured paste takes place. During this process, the applied coloured paste reacts with the fabric to form a permanent bond.

An additional process step can take place, namely the stentering of the printed fabric. The fabric is led through a stentering machine, which is also heated by gas. Here the fabric is stretched in width in order to make up for the size-losses occurred during the printing and curing process.

When the printing job is finished, the excess coloured paste is scraped-off. Once this is done, the printing screens are taken out and the excess coloured paste is washed off. The cleaned screens are stored for possible repeat orders. The screens, which will not be reused, are sent back to the screen engraving company for reprocessing. Reprocessing concerns removing the old emulsion and applying a new emulsion layer on the screen.

4.3.3 Environmental Profile

Water Use

The most water intensive processes of the textile company are the rotary printing process and the cleaning of the rotary screens.

Large quantities of water are used during the printing process. The blanket becomes contaminated with coloured pastes while transporting the fabric through the printing machine. The blanket, therefore, needs to be cleaned with water; or else it will contaminate the fabric while rotating in the printing machine.

The cleaning of the screens after printing can be done manually or automatically. A fully automatic screen washing machine has been installed at the plant; this machine uses much less water to clean each screen than if it is done manually. However it does not clean the screen thoroughly. Therefore, the screens are often manually washed-off again with a relatively large amount of water. It is expected that the textile printer will eliminate this inefficiency in the near future.

Effluent Water

The effluent water of the textile printing company is contaminated mainly with coloured pastes. A wastewater settling tank separates the coloured paste from the effluent before disposing it into the sewer. However, the settling tank can only treat 25% of the wastewater from the printing machines.

Another contaminant (of the textile company's effluent) is the screenwash, which is considered to be hazardous. The screenwash is used to remove the left-over coloured pastes from the rotary screens. Both the screenwash and the dissolved emulsion are disposed into the sewer.

The wastewater from the printing process is also contaminated with the glue that is used to stick the fabric onto the blanket. However, this is not regarded as a major concern. The glue contains polyvinyl alcohol and is not considered hazardous; the glue is applied in diluted form.

Solid Waste (Coloured Paste)

On completion of a print job, there is always left-over coloured paste because more coloured paste is made than is actually necessary. Extra coloured paste compensates for process faults or unforeseen situations. It would be a loss of valuable capital and human resources if the printing machine has to be stopped due to a shortage of coloured paste.

The textile company has a so-called colour-kitchen which enables the transformation of used coloured pastes into coloured paste with a new colour. Each coloured paste has its own recipe, which means that the composition of each formulated coloured paste (mixture of pigments with paste components such as binder, hardener, softener) is unique. The coloured paste's recipe depends on the characteristics of the design, the used fabric and the printing machine. The company's years of experience has led to the formulation of the required recipe of a coloured paste for each job. The recipes of all stored coloured pastes are saved in the database of the colour kitchen machine. A new coloured paste can be composed of the left-over coloured paste. This is financially and environmentally attractive as no or fewer newly bought raw materials have to be used.

However, not all waste coloured pastes can be reused because it is often not possible to transfer a dark colour coloured paste into a lighter colour. There are also limitations to the time-span over which coloured pastes can be stored. For these reasons, a part of the used coloured pastes have to be disposed of as hazardous waste.

Energy Use

The most energy-intensive processes of the textile company are the curing and stentering of the printed fabric. Both machines are heated by gas. Although the curing and stentering are energy-intensive processes, they are regarded as energy-efficient because they are technologically advanced.

The printing process can also be considered to be energy-intensive, although less so than the curing and stentering process. The two rotating printing machines are electrically-powered.

4.4 Waste Minimisation Activities conducted at Textile Printing Company

Although a full waste minimisation assessment was not conducted at the textile printing company, a waste minimisation pre-assessment report was completed and a follow-up project was started to reduce their water consumption. These two projects are described in the following subsections.

4.4.1 Waste Minimisation Pre-Assessment Report

The waste minimisation pre-assessment report of the textile company was written by a student at the Department of Chemical Engineering of the University of Cape Town as part of his practical internship for a Bachelor of Science Degree in Chemical Engineering [Wright, 1998].

The aim of this report was to get an initial overview of the company's operations, waste streams and emissions in order to establish the focus areas for the waste minimisation assessment.

The focus areas selected for the textile printing company were:

- *Water consumption:* the rotary printing process and the cleaning of the screens after printing are water-intensive process and have a high waste minimisation potential through good housekeeping and technology changes.
- *Waste coloured paste:* it was estimated that 15% of the coloured paste is not transferred onto the fabric. For both the rotary and the flatscreen plant, roughly 10,000 kg of wasted coloured paste is disposed of per year as hazardous waste. The cost of raw material that will be required to make-up one kg of coloured paste is considered to be relatively high, approximately 3.50 ZAR per kg.
- *Pollution of effluent:* during the printing process and cleaning of the used printing screen, the water becomes contaminated with coloured pastes, which have a negative impact on the BOD of the effluent. Good housekeeping practices and technology changes could probably reduce the water pollution caused by the textile company.

The waste minimisation assessment was not completed as no students could be found with the required expertise and time to carry out this project.

4.4.2 Water Consumption Project

Although a full waste minimisation assessment was not carried out at the textile company, a Dutch student followed-up on the recommendation of the waste minimisation pre-assessment to investigate the possibilities of reducing the water consumption at the company. This project was part of her internship for the Degree of Bachelor in Environmental Engineering at the Hogeschool Delft in the Netherlands [Bakker, 1999]. Only the rotary plant was taken into consideration for this assessment because it is responsible for 94% of the water consumption.

A detailed assessment of the water consumption was carried out to determine the exact amount of water flowing through the company and, subsequently, to generate improvement options to reduce the water consumption. Water meters were also installed in order to get a correct water balance for the rotary plant. The water balance indicated the amount of water that was used by each process step.

A brainstorming session was held with the production staff in order to generate options to reduce the water consumption at the company. A presentation about waste minimisation and its benefits was given to the participants before starting the actual brainstorming session. 23 options were generated during the brainstorming session, of which 8 were selected for further investigation. A description of these selected prevention options and their financial savings can be found in Appendix F.

4.5 Conducted Experiments with the Industrial Network Approach at the Textile Printing Company

This section and the following sections discuss the experiments and results of the developed industrial network approach at the textile printing . The evaluation of the developed methodology itself is outlined in Chapter 6.

The experiments were facilitated by the author of this thesis. He was therefore responsible for the co-ordination and the results of the conducted experiments at the textile company.

During the inventory phase, the industrial network of the textile printer was mapped out. This exercise was carried out over a period of three weeks. Meetings were held with various staff members as knowledge and expertise of the particular network sections (eg. suppliers, clients, competitors, waste treatment organisations) were not concentrated in the company. During these meetings, the network mapping worksheets were completed and the mapped network was discussed. Appendix G shows the full-size mapped network of the textile printing company.

As outlined in Chapter 3, two tools are proposed to identify eco-efficient improvements in the industrial network of a company, namely, a network brainstorming session and a network impact matrix. At the textile printing company, the network brainstorming sessions were held first. The network impact matrix was conducted once the brainstorming sessions were completed.

The brainstorming session was held with the managing director of the case-study company and led by the facilitator of the experiments. Three sessions, each of approximately one hour, were required to discuss all questions on the network brainstorming checklist. The completed checklist of the textile printing company can be found in Appendix H.

The network impact matrix was conducted by the facilitator over a period of 2 months. Missing data was provided by staff members and network partners of the textile company. The completed network impact matrix is included in Appendix I.

The potential improvements, identified during the network brainstorming session and in the network impact matrix, were then summarised and discussed with the managing director of the company in order to select the options with the highest potential. In terms of time, it is not viable to conduct a feasibility analysis on all identified options. One meeting of approximately 2 hours was required to discuss the identified options and make a selection of the potentially most feasible options.

The feasibility analysis incorporated an environmental, economic, technical and social evaluation of the selected improvement options. The facilitator of the industrial network assessment completed the feasibility study with assistance from staff members, network partners of the textile printing company and industry specialists. Approximately ten full working days were used to conduct the feasibility analysis.

4.6 Description of the Industrial Network of the Textile Printing Company

The first step in the process of the industrial network assessment is the illustration of the company's industrial network. The full-size mapped network of the textile company can be found in Appendix G. Each section of the industrial network is discussed separately in the following subsections.

4.6.1 Shareholders

Roughly ten years ago, the textile printer was taken over by its current owners. The textile company is currently owned by an international investment company and the managing director of the company. All major investments have to be approved by the holding company. The day-to-day business of the company is conducted by the managing director. There is regular contact between the managing director and the investment company. They discuss the company's financial performance and required investments.

4.6.2 Suppliers

The following product categories are supplied to the textile printing company:

- process chemicals
- gas / fuel / oil
- packaging
- tools / machinery

The textile printing company works closely with a foreign company that supplies it with pigments and paste components. Approximately 80% of the process chemicals are supplied by this company. Although the prices of their products are higher than their competitors, mainly because the products have to be transported from Europe and the low exchange rate of the ZAR against the US dollar , the textile company prefers to work with this particular supplier. The reason for doing so, is the high quality and reliability of their products. The other suppliers of process chemicals are all South African companies.

As for the suppliers of gas, fuel, oil and packaging, there is only a "buy-sell" relationship which is mainly driven by price and delivery time.

4.6.3 Clients

The textile printing company does not export its products. The majority of the clients are based in the Cape Town region, however the textile company also supplies customers in the Durban and Johannesburg area. The clients are either clothing manufacturers or design houses.

The clothing manufacturers have in-house textile processes such as designing, CMT (cut, make and trim) and knitting. They send the fabric to the textile company to be printed, after which it is sent back to the clothing manufacturer.

The design houses do not have in-house textile processes. They make the clothing design and contract external companies to process the textile product. However, the design houses are responsible for the quality of the end-product and the delivery-time. The design houses play a significant role in the network of the textile printing company because they decide who will be contracted and under what conditions.

For local clients, the collection and delivery of fabric largely the responsibility of the client. Only for a few local clients is the transport arranged by the case-study company. An external company is used to transport fabric to and from clients located around the Durban and Johannesburg areas.

The communication between the textile printing company and its clients is based on quality, price and delivery time; environmental issues are rarely discussed.

The textile company does not depend on one or a few major clients for its profitability. Many different clients make up the order pocket.

4.6.4 Competitors

The main competition to the textile printing company comes from various local and national commissioned printers and textile mills. The textile mills have an advantage in that they have the capacity of both producing and printing the textiles. The competition from these mills is increasing.

It is the opinion of the textile printing company that the competition is too tight to meet with the competitors and exchange ideas. It also believes that the acquisition and deployment of advanced technology is the main success factor of gaining competitive advantage.

4.6.5 *Utility Providing Organisations*

The local government provides the textile printing company with water and electricity. Eskom is the generator of electricity. Inspectors of the government take regular samples of the effluent water.

There are regular meetings with Eskom to discuss opportunities to improve the energy efficiency within the company. There is only personal contact with local government in case there are problems with the effluent quality, effluent sampling procedure or the water bill.

4.6.6 *Waste Treatment and Recycling Companies*

All waste treatment and recycling companies, used by the textile printing company, are located locally. The process sludge, which consists of waste coloured paste and other process chemicals, is brought to a local landfill site by the company themselves. The textile company has obtained a permit from the local government to do this. This saves the company the cost of hiring a waste "treatment" company to transport the waste to a landfill site. General industrial waste is collected by the waste services department of the local government who dispose it on one of the government-owned landfill sites in the Cape Town area. The local community collects the plastic waste of textile printing company; they take it to the plastic recycling depots in order to be recycled by a plastic manufacturer. The misprints and printed fabric that are rejected for quality reasons are sold to a local fabric shop.

The intensity of personal contact between the textile printing company and the waste treatment / recycling companies is low. The only contact that takes place is the setting up of appointments for waste collection and conducting payment for services delivered.

4.6.7 *Support Organisations*

Only 20% of the employees of the textile company are a members of South African Clothing and Textiles workers Union (SACTWU). Members of this employee organisation have to stick to a basic salary; although most of the employees of the case-study company get paid more. This is the reason why most employees choose not to be a member of SACTWU.

The textile company is affiliated to SACTPEA, which stands for South African Cotton Textile Processing Employers Organisation. The textile company sees SACTPEA as the connection between managers in the textile industry and the government with regard to wage negotiations. The objectives of SACTPEA are to represent its members in negotiations with the South African government concerning matters affecting the cotton textile manufacturing industry and to collect and disseminate information likely to be of use to its members.

An accounting firm is contracted to claim subsidies on behalf of the textile printing company from the Regional Industrial Development Programme of the Department of Trade and Industry.

4.6.8 *Government and Community Organisations*

The relationship between the case-study company and the local government is discussed in the Subsection 4.6.5 "Utility proving organisations".

The textile company, along with its employees, sponsor a community organisation called Community Chest, which supports underprivileged people in South Africa.

4.6.9 Maintenance

The textile company only contracts a maintenance company if the repair or maintenance can not (cannot) be done in-house. All maintenance companies are based locally.

The repair / maintenance usually involves:
- electrical equipment
- production machinery (mechanical)
- the production plant
- plumbing

The textile printing company does not depend on a specific maintenance company for its repair or maintenance, although it aims to work with the same group of maintenance companies.

4.7 Evaluation of Results of Industrial Network Assessment

4.7.1 Total Overview of Results

Table 4.2 gives an overview of the potential improvement options generated by the industrial network assessment.

For each option, it was determined whether it is an internal or an external improvement option. The difference lies in the extent of the economic, technical and social impact of the improvement options. The environmental impact is, per definition, outside the company's physical boundaries. An internal improvement can be defined as an improvement option which "only" has an economic, technical and social impact within the company's physical boundaries. An external improvement option can be defined as an improvement option that has an economic, technical and social impact inside and outside the company's physical boundaries. The external improvement options have a strong networking character and require co-operation from one or more partners within the company's industrial network.

Ref. no.	Additional improvement options identified by industrial network approach	Internal or external improvement option?
1.	**Energy**	
1.1	Usage of alternative energy for heating processes.	Internal
2.	**Environmental management**	
2.1	Better utilisation of the services offered by support organisations.	External
2.2	Utilisation of available environmental incentive schemes from the government.	External
2.3	Optimisation of handling and washing requirements of clothing.	External
3.	**Inspection / control / maintenance**	
N.A.	No identified improvement options for "Inspection/control/maintenance".	N.A.
4.	**Packaging**	
4.1	Improvement of packaging, transport standards and efficiency within client-part of textile company's network.	External
4.2	Reuse of plastic foil to wrap printed fabric instead of using new plastic foil.	Internal
4.3	Reduction of environmental impact of packaging of supplied chemicals.	Internal.
5.	**Process optimisation**	
5.1	Application of JIT-principle at textile printing company.	External

Ref. no.	Additional improvement options identified by industrial network approach	Internal or external improvement option?
5.2	Replacement of currently used hazardous process chemicals by available less hazardous alternatives.	Internal
6.	**Product design**	
6.1	Obtain approval for the EU Eco-labeling scheme.	External
7.	**Transport**	
N.A.	Included in option 4.1	External
8.	**Wastes**	
8.1	Assessment of general waste for valuable, recyclable components.	Internal
8.2	Participation in waste exchange programme.	External

Table 4.2 Overview of Results of Industrial Network Assessment

4.7.2 Screening of Identified Options

Although a full waste minimisation assessment has not been conducted at the case-study company, the options, identified by the developed industrial network assessment, will probably be identified by a waste minimisation assessment as well. Table 4.3 indicates those options that are typical waste minimisation options. Therefor, these options do not add value to the developed industrial network assessment.

The internal and external improvement options are discussed separately in the following subsections.

Ref. no.	Improvement options identified by industrial network assessment	Would have been identified by waste minimisation assessment?
Internal improvement options:		
1.1	Usage of alternative energy for heating processes.	Yes
4.2	Reuse of plastic foil to wrap printed fabric instead of using new plastic foil.	Yes
4.3	Reduction of environmental impact of packaging of supplied chemicals.	Probably not, not main focus of waste minimisation methodology
5.2	Replacement of currently used hazardous process chemicals by available less hazardous alternatives.	Yes
8.1	Assessment of general waste for valuable, recyclable components.	Yes
External improvement options:		
2.1	Better utilisation of the services offered by support organisations.	No, outside scope of waste minimisation methodology
2.2	Utilisation of available environmental incentive schemes from the government.	No, outside scope of waste minimisation methodology
2.3	Optimisation of handling and washing requirements of clothing.	No, outside scope of waste minimisation methodology
4.1	Improvement of packaging, transport standards and efficiency within client-part of textile company's network.	No, outside scope of waste minimisation methodology
5.1	Application of JIT-principle at textile printing company.	No, outside scope of waste minimisation methodology
6.1	Obtain approval for the EU Eco-labeling scheme.	No, outside scope of waste minimisation methodology

Ref. no.	Improvement options identified by industrial network assessment	Would have been identified by waste minimisation assessment?
8.2	Participation in waste exchange programme.	No, outside scope of waste minimisation methodology

Table 4.3 Screening of the Internal and External Improvement Options

4.7.3 *Evaluation of Internal Improvement Options*

The aim of the industrial network assessment is to identify eco-efficient improvements in the industrial network of the textile printing company, the so-called external improvement options. The internal options, therefore, do not add value to the developed industrial network approach. However, the internal options will be discussed briefly in order to give an impression of the environmental improvement potential of the case-study company.

4.7.3.1 *Evaluation of Internal Options – Typical Waste Minimisation Options*

Table 4.4 gives an overview of the internal improvement options, identified by the industrial network assessment, which would most probably have been identified by a waste minimisation assessment. For each option, it is indicated if it was selected for a feasibility analysis and whether the option is estimated to be feasible or not.

Ref. no.	Internal improvement options – typical waste minimisation options	Selected for feasibility analysis?	Estimated feasible?
1.1	Usage of alternative energy for heating processes.	No	N.A.
4.2	Reuse of plastic foil to wrap printed fabric instead of using new plastic foil.	Yes	Yes
5.2	Replacement of currently used hazardous process chemicals by available less hazardous alternatives.	Yes	Yes / No
8.1	Assessment of general waste for valuable, recyclable components.	No	N.A.

Table 4.4 Internal Options – Typical Waste Minimisation Options

<u>Use of Alternative Energy for Heating Purposes</u>

Option 1.1 concerns the application of alternative energy in the printing, curing and/or stentering process that are regarded as the three most energy-intensive processes of the textile company. Gas is used to heat up the curing and stentering machines and the rotary printing machines run on electricity.

This option was not selected for a feasibility study because the alternative energy can not meet the high energy requirements of the printing, curing and stentering process. Additionally, the electricity costs (ZAR per kWh) are extremely low in South Africa and the investment costs for alternative energy equipment (eg. solar energy) are considered to be high. These observations do not make the investment in alternative energy cost effective.

<u>Reuse of Plastic Foil to Wrap Printed Fabric Instead of Using New Plastic Foil</u>

The incoming fabric, supplied by the clients of the textile printing company, is wrapped in plastic foil. The plastic foil is collected by the local community who sell the it to a plastic recycling company. After printing, the fabric is wrapped again in new plastic foil and sent back to its clients.

Although the waste plastic is externally recycled, it would be more efficient, in terms of raw material use and costs, to use the plastic foil to wrap up the printed fabric.

Sometimes, the incoming plastic foil is slightly damaged or dirty. Therefore, new plastic foil is used for aesthetic reasons. It is the perception of the textile company that packaging reflects the quality of the product. Approximately 10,000 kg of plastic and tape is used annually, mainly for packaging purposes.

If the company decides to reuse its plastic foil, the costs on raw materials are reduced. No technical changes are required to implement this option. It is therefore considered to be environmentally, economically and technically feasible. However, the social barriers, as described above, have to be overcome. The sharing of the financial benefits between the textile company and its clients could be an incentive for the involved parties to implement this option.

<u>Replacement of Currently Used Hazardous Process Chemicals by Less Hazardous Alternatives</u>

The case-study company currently uses various kinds of printing and other process chemicals for which less hazardous materials are available.

The textile printing company did not receive the Material Safety Data Sheets (MSDS) for all the chemicals used in the production process. The suppliers were asked to send the missing MSDS to the textile company. Based on these MSDS, it could be determined which chemicals are hazardous and have a potentially negative environmental effect.

Less hazardous alternatives should be investigated for the following printing/process chemicals:

- various ready-made print pastes which contain hazardous substances such as white spirits, titanium dioxide, chloride polymer, ethylene glycol or formaldehyde;
- a fixing agent which contains formaldehyde;
- a thickener based on white spirits;
- a pigment which contains heavy metals (copper and zinc);
- a glue, which is used to stick the fabric on the blanket of the rotary printing machine, contains methanol;
- a dissolving liquid for a glue which contains dichloromethane and organic solvents.

Priority should be given to the substitution of the most expensive, used and polluting chemicals. For example, the textile printing company spends approximately 40,000 ZAR per year on a dissolving liquid for a glue which is used to stick a metal ring to rotary printing screen in order to install the rotary screen in the printing machine. A less hazardous and less expensive alternative product might be available for the glue and its dissolving liquid.

The assessment of less hazardous chemicals was not done as this option is a typical waste minimisation option and therefore does not add value to the developed industrial approach.

<u>Assessment of General Waste for Valuable, Recyclable Components</u>

The general industrial waste and sludge (waste coloured pastes and process chemicals) of the textile printing company might contain valuable materials, such as reusable cardboard, paper and plastics and perhaps even process chemicals which could be reused internally.

This option was not selected for a feasibility analysis as the managing director believed that more urgent environmental matters should be addressed first.

4.7.3.2 Evaluation of Internal Options – Not Main Focus of WM-methodology

Table 4.5 shows an internal improvement option which would most likely not have been identified by a waste minimisation assessment as this option is not the main focus area of the waste minimisation methodology (see Subsection 2.4.3.3 "Main Focus of WM-methodology" of the literature review).

Ref. no.	**Internal improvement options – Not main focus of WM-methodology**	**Selected for feasibility analysis?**	**Estimated feasible?**
4.3	Reduction of environmental impact of packaging of supplied chemicals.	Yes	Yes

Table 4.5 Internal Option – Not Main Focus of WM-methodology

Most of the printing and process chemicals are supplied in plastic containers. There a several possibilities for reducing the environmental impact of the packaging of the chemicals supplied to the textile printing company.

A large part of the supplied chemicals are packed in containers with a plastic bag inside. This prevents the plastic containers from getting contaminated with the content chemical. In this way, the container stays suitable for reuse and recycling. The contaminated bag is disposed as hazardous waste. All suppliers should aim to apply this packaging system in order to make it easier for companies to reuse or recycle their plastic containers. The textile printing company uses the empty containers to store (waste) coloured pastes. If a plastic bag is not inserted, then the cans must be cleaned before reuse or recycling. It is likely that the printing / process chemicals still left in the container are disposed into the sewer, possibly without any treatment.

As for the containers that are not reused by the textile printing company, the supplier can provide a take-back service. Additionally, the packaging of the supplied chemicals could be assessed on the basis of material diversity, recyclability and reusability; perhaps certain packaging require special disposal practices.

There is improvement potential for the reduction of the environmental impact of the packaging. It is estimated that the implementation of this option is feasible for the textile printing company.

4.7.4 Evaluation of External Improvement Options

The external improvement options, as identified by the industrial network assessment, are evaluated in Table 4.6.

Ref. no.	**External improvement options**	**Selected for feasibility analysis?**	**Estimated feasible for company?**	**Estimated feasible in network?**
2.1	Better utilisation of the services offered by support organisations.	Yes	Yes	N.A.
2.2	Utilisation of available environmental incentive schemes from the government.	Yes	No	N.A.
2.3	Optimisation of handling and washing requirements of clothing.	Yes	No	Yes
4.1	Improvement of packaging, transport standards and efficiency within client-part of textile company's network.	Yes	Yes	Yes

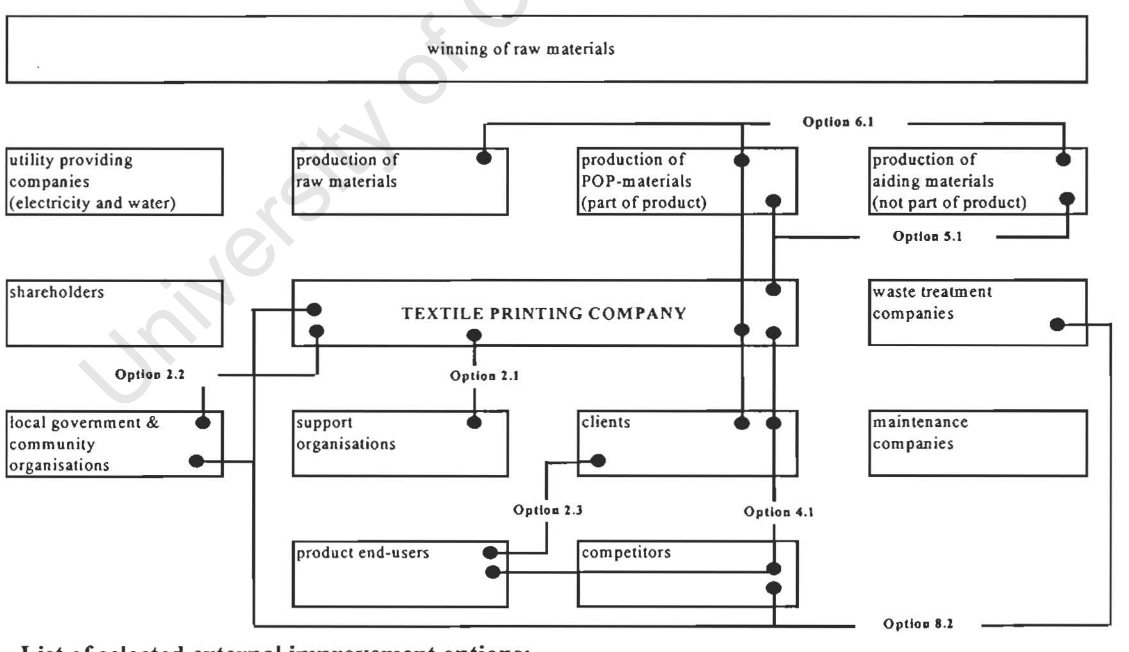
Ref. no.	External improvement options	Selected for feasibility analysis?	Estimated feasible for company?	Estimated feasible in network?
5.1	Application of JIT-principle at textile printing company.	Yes	No	N.A.
6.1	Obtain approval for EU Eco-labeling scheme.	Yes	No	Yes
8.2	Participation in waste exchange programme.	Yes	Yes	N.A.

Table 4.6 Evaluation of External Improvement Options

A rough feasibility analysis was conducted for the external improvement options in order to estimate the practical viability thereof. The feasibility concerned an environmental, economical, technical and social evaluation of each option.

An external improvement option might not be feasible for the textile printing company. It can, however, be a feasible option for one or more network partners of the case-study company (indicated in the last column of Table 4.6).

Figure 4.3 illustrates how the selected external improvement options fit into the industrial network model and which network sections should get involved to successfully implement the improvement option. The following subsections will discuss each option in detail.



List of selected external improvement options:

Option 2.1	Better utilisation of the services offered by support organisations.
Option 2.2	Utilisation of available environmental incentive schemes from the government.
Option 2.3	Optimisation of handling and washing requirements of clothing.
Option 4.1	Improvement of packaging, transport standards and efficiency within client-part of textile company's network.
Option 5.1	Application of JIT-principle at textile printing company.
Option 6.1	Obtain approval for the EU Eco-labeling scheme.
Option 8.2	Participation in waste exchange programme.

Figure 4.3 External Improvement Options Linked with Industrial Network Model

4.7.4.1 Option 2.1: Better Utilisation of Services Offered by Support Organisations

A classification of option 2.1 is given in Table 4.7.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session	X		Question 2.8 and 8.8 in brainstorming checklist (App. H)	
Network impact matrix		X	N.A.	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network		X		Option can apply to all environmental concerns (material choice, energy use, solid/liquid/gaseous residues)
Financial flow(s) in industrial network			X	
Information flow(s) in industrial network	X			

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 4.7 Classification of External Option 2.1

The textile printing company continuously explores the opportunities to expand its markets. A way to expand the company's business activities is by entering the market of "environmentally friendly" textile products. Industry organisations or other support organisation may be able to help the case-study company in exploring and marketing this option. The services of the Directorate Textile, Clothing and Footwear, the Department of Trade and Industry and Textek (the textile division of the CSIR) should be assessed in this regard.

The textile company is also interested in giving its employees who work with hazardous chemicals training on how to handle these chemicals. This will minimise the risk of harm to employees' health and to the environment. Support organisations, in particular Textek and the Textile Training Board, might offer suitable training courses.

Although the potential possibilities of this option was not fully explored, due to time-constraints of the conducted experiments, it is estimated that this option is feasible. It is up to the case-study company to contact the various support organisations in order to find out if they can provide the company with environmental training courses and information regarding new emerging "green" markets.

An overview of the support organisations that are related to or specialised in the South African textile industry is given in Appendix E.

4.7.4.2 Option 2.2: Utilisation of Available Environmental Incentive Schemes

A classification of option 2.2 is given in Table 4.8.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session	X		Question 2.10 in brainstorming checklist (App. H)	
Network impact matrix		X	N.A.	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network		X		Option may indirectly improve all environmental concerns (material choice, energy use, solid / liquid / gaseous residues)
Financial flow(s) in industrial network	X			
Information flow(s) in industrial network			X	

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 4.8 Classification of External Option 2.2

The South African government has various financial incentive schemes available to promote the business development of SMEs. The growth of the SME-sector is a keyfactor in promoting economic growth, social equity and employment creation. Incentive schemes are controlled by the Department of Trade and Industry (DTI) or the Industrial Development Corporation (IDC). Although the IDC is a government owned organisation, the corporation's autonomy and independence is guaranteed. The IDC has been set up to assist in the development and expansion of the South African manufacturing sector [Naumann, 2000b].

There is only one incentive scheme available that aims to encourage SMEs to improve their environmental performance - the IDC's Cleaner Production Scheme. This scheme provides financing with interest rates of up to 2% below the prime rate in South Africa. The financing should be used for the modernisation of existing plant and equipment, the expansion of existing industries and the establishments of new ventures aimed at cleaner production technologies [DTI, 1997].

The case-study company regularly invests in the latest printing technologies as technology advancement is one of the key factors of the company's competitive advantage. These new technologies improve the process efficiency and therefore, in most cases, reduce the negative impact on the environment as fewer raw materials and energy are used. An example of such an investment is the automatic colour kitchen, which the textile company bought in 1998; this machine enables the company to reuse a part of the used coloured pastes internally.

The textile printing company could apply for a loan with the reduced interest rate from IDC's Cleaner Production Scheme for future investments. However, the textile company will not benefit from this scheme because it can get financial assistance from its holding company at an even lower interest rate. Additionally, the application process for a loan via the Cleaner Production Scheme was regarded as complex and time-consuming, with no guarantee of success. Based on these reasons, this external option is not considered to be feasible.

4.7.4.3 *Option 2.3: Optimisation of Handling and Washing Requirements of Clothing*

A classification of option 2.3 is given in Table 4.9.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session	X		Question 2.6 in brainstorming checklist (App. H)	
Network impact matrix	X		Product handling by first, second and third clients (App. I)	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network		X		Option will reduce material and energy use and liquid (water) emissions
Financial flow(s) in industrial network			X	
Information flow(s) in industrial network	X			

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 4.9 Classification of External Option 2.3

A life cycle assessment on a cotton men's shirt carried out by Diehl [1994] showed that the user phase is responsible for most of the waste generation and the energy use. Although this LCA was only carried out on a cotton men's shirt, it is stipulated that the waste generation and energy use of clothing in general is the most significant during the user phase.

During the user phase, the clothing is washed, dried and ironed many times. The material and energy use could be reduced if these activities were optimised. For example, instead of washing at 60 degrees or even 90 degrees Celcius, clothing could be washed at 40 degrees Celcius. The amount of washing powder used is also an important factor.

This improvement option concerns changing the handling and washing instructions printed on the labels into ones that are more material and energy efficient. This reduces the environmental impact during the user phase. Besides the recommended washing temperature, suggestions could be printed on the clothing labels as to how the consumer can save money on material (eg. washing powder and water) and energy costs. In this way, the consumers become educated on how to handle and wash their clothing as efficiently as possible.

It is not the textile printing company's responsibility to determine what is printed on the clothing labels. The case-study company is a commissioned printer; it only prints the fabric which is supplied by its clients. The fabric manufacturing is not part of their production process and the textile printing company does also not have direct contact with the clothing retailers that sell the clothing to the product end-users. There is no incentive for the textile company to implement this option and it is therefore regarded as not feasible.

The technical implications for the case-study company of implementing this options are limited or nil. This is because all printing chemicals applied by the company should be able to handle the suggested changes in the user conditions (for example warmer or colder washing temperatures).

Although the option is not feasible for the textile printing company, it can be a feasible option for the clothing manufacturers, design houses and clothing retailers.

4.7.4.4 *Option 4.1: Improvement of Packaging, Transport Standards and Efficiency*

A classification of option 4.1 is given in Table 4.10.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session		X	N.A.	
Network impact matrix	X		Product handling by first, second and third clients (App. I)	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network	X			Option will improve material choice, reduce material and energy use, solid and gaseous emissions
Financial flow(s) in industrial network	X			
Information flow(s) in industrial network			X	

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 4.10 Classification of External Option 4.1

The facilitator of the industrial network assessment had meetings with several clients of the company. These meetings revealed that the packaging and transport efficiency of the client part of the textile printer's network are low.

As shown in the mapped industrial network of the case-study company (Appendix G), the client-section of the network is characterised by two-way material flows with high intensities because a significant number of companies are involved in the manufacturing process of textiles and clothing. It was found that each time the textile/clothing product is transported to another location for processing, the processed materials are wrapped and packed extensively in various types of plastic, paper and cardboard.

One of the reasons for the extensive use of packaging, is the (perceived) low standard of transport companies in South Africa. Companies are afraid that the products will get damaged during transport and that they will be held responsible for the damage by their clients.

The clothing retailers also contribute to the extensive packaging waste generated in the textile chain because they set the packaging requirements for the clothing sold in their outlets. The packaging of clothing is perceived to add value to the sold products. Besides protecting the clothing against damage or stains, packaging also has a decorative function.

It was observed that a large part of the used packaging is not reused but disposed as domestic waste or is collected by the local community for external recycling. There is improvement potential for the reduction and improvement (material recyclability and diversity) of packaging and its related costs. A project to improve the packaging efficiency could be started up within the client-section of the case-study company's industrial network.

Possible means of improving the transport standard and efficiency should be assessed as well. The environmental aspects of the low transport standards concern the generally poor condition of trucks and the poor utilisation of the available transport space; both aspects cause high(er) truck emissions. Companies in the textile/clothing chain could possibly set-up a joint contract with an external transport company. By doing so, the transport standard and efficiency can be guaranteed on-time delivery and collection, transport vehicles adjusted to their clients' needs, making full use of transport space etc.).

It would be feasible for the case-study company to take part in a packaging reduction project. The company can save money on packaging and obtain long-term commitment from their clients by joining such a project.

4.7.4.5 *Option 5.1: Application of JIT-principle at the Textile Printing Company*

A classification of option 5.1 is given in Table 4.11.

<table>
<tr><th>Option was generated by:</th><th>Yes</th><th>No</th><th colspan="2">Reference</th></tr>
<tr><td>Network brainstorming session</td><td>X</td><td></td><td colspan="2">Question 2.1 in brainstorming checklist (App. H)</td></tr>
<tr><td>Network impact matrix</td><td></td><td>X</td><td colspan="2">N.A.</td></tr>
<tr><td>Options aims to optimise:</td><td>Direct *</td><td>In-direct*</td><td>No</td><td>Environmental benefits of option:</td></tr>
<tr><td>Material flow(s) in industrial network</td><td>X</td><td></td><td></td><td rowspan="3">Option will limit the risks of ageing, leaking and accidental losses</td></tr>
<tr><td>Financial flow(s) in industrial network</td><td></td><td>X</td><td></td></tr>
<tr><td>Information flow(s) in industrial network</td><td></td><td></td><td>X</td></tr>
</table>

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 4.11 Classification of External Option 5.1

Just-In-Time (JIT) is a management philosophy that strives to eliminate sources of manufacturing inefficiencies by producing the right part in the right place at the right time. Manufacturing inefficiencies, as defined by JIT, results from any activity that adds costs without adding value, such as moving and storing.

The principle of JIT is to establish flow processes by linking work centres so that there is an even, balanced flow of materials throughout the entire production process, similar to that found in an assembly line. In order to accomplish this, an attempt must be made to drive all queues toward zero and achieving the ideal lot size of one unit.

The textile printing company could possibly benefit from the JIT-principle to reduce inventory levels, improve product quality, reduce production and delivery lead times. JIT applies primarily to repetitive manufacturing processes in which the same products and components are produced over and over again. The company's production process does not meet those criteria as almost all printing jobs are unique and printed in accordance with specific requirements from the clients. This option is therefore regarded as unfeasible for the textile printing company. However, the case-study companies tries to keep its stocks as low as possible in order to limit the associated costs and risks of ageing, leaking and accidental losses.

4.7.4.6 Option 6.1: Obtain Approval for EU Eco-labelling Scheme

A classification of option 6.1 is given in Table 4.12.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session	X		Question 6.4 in brainstorming checklist (App. H)	
Network impact matrix	X		Product handling by first, second and third clients (App. I)	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network		X		Option may indirectly improve all environmental concerns (material choice, energy use, solid / liquid / gaseous residues)
Financial flow(s) in industrial network		X		
Information flow(s) in industrial network	X			

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 4.12 Classification of External Option 6.1

The interest in Europe for "environmentally friendly" textiles is growing due to the increasing environmental awareness among end-consumers. In developing countries, such as South Africa, this market is limited due to the low consideration of the environment when considering product purchases [Hyvarinen, 1996]. The South African market is mainly driven by price, and to a less extent, quality. The export market is the main market for "green" textiles manufactured in South Africa. This means that potential export clients have a great influence on how the production of "green" products will develop in South Africa.

There are various textile eco-labels in Europe, all of which are voluntary: some are national, while others are so-called "private" labels, which cover a wider geographic area. Eco-labelling criteria for textiles have only existed for three years now, and different eco-labelling schemes have not yet matured [Burdett, 1997].

Option 6.1 "Obtain approval for EU eco-labelling scheme" assesses the extent to which the textile printing company meets the requirements of the EU eco-labelling scheme. If the case-study company decides to obtain EU eco-label approval, it can use this scheme as a marketing instrument to enter the international market. The EU eco-labelling scheme has been chosen because it is believed that this scheme will be the new standard for the European market [Tascher, 1997]. Additionally, the EU eco-labelling scheme is based on the product's impacts on the environment during its entire life cycle whereas most other schemes tend to focus only on the finished products.

The objective of the EU eco-labelling scheme is to promote the design, marketing and use of products that have a low environmental impact during their entire life cycle. It also provides consumers with better information on the environmental impact of the products without significantly compromising on the properties that make a product fit for use.

In order to obtain EU eco-labelling approval for the textile company, both the rotary and flatscreen printing process have to meet the requirements. An assessment of the company's processes showed that the textile company currently does not meet the requirements of the EU eco-labelling scheme on the following criteria:

- Insight is needed into the chemical composition of the screenwash and the stripping agent used at the rotary plant as heavy metal salts (except for iron) or formaldehyde are not allowed to be used for stripping and depigmentation.
- The gold pigment contains Zinc and Copper. A detailed assessment is needed to determine whether the concentration of these heavy metals is within the limits.
- The maximum concentration of VOC-compounds allowed in coloured paste is 5%. The solvent-based coloured pastes used at the flatscreen plant certainly do not meet this requirement. Further investigation is required to establish whether the water-based coloured pastes, used at the rotary plant, meet these requirements as certain paste components (for example a thickener) contain VOC compounds.
- Formaldehyde is not allowed to end-up in the end product. A type of fixing agent and a ready-made-print paste used by the textile company contain formaldehyde.
- A detailed analysis of the waste water is required to determine whether the COD level of the effluent is within the limits of the EU Eco-labelling scheme (less than 2500 mg/liter).
- Tests are required to assess whether the case-study company meets the "fitness for use" requirements. These requirements concern dimensional changes during washing and drying, colour fastness to wet and dry rubbing etc.

This list shows that the textile printing company has to invest a considerable amount of effort and apply various process changes in order to meet all requirements of the EU eco-labelling scheme. Appendix J includes a detailed assessment the EU eco-labelling requirements and its application at the textile printing company.

It is the opinion of the author of this thesis that it is not feasible for the textile company to obtain EU eco-labelled approved as the national market is characterised by a low environmental awareness and mainly driven by price and delivery-time. By applying an eco-label, the textile company will only increase its costs without increasing its revenues by increasing its share in the local market.

If the intentions of the case-study company are to enter the international market, it might be feasible in the long-term to obtain approval from the EU eco-labelling scheme or another eco-label. However, it would still be advisable to wait until eco-labelling criteria for textiles have matured more and are more common practice in Europe and other international markets.

4.7.4.7 Option 8.3: Participation in Waste Exchange Programme

A classification of option 8.3 is given in Table 4.13.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session	X		Question 8.2 in brainstorming checklist (App. H)	
Network impact matrix	X		Processing waste of SME by external waste treatment / recycling companies (App. I)	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network	X			Option will improve material choice, reduce solid and liquid emissions
Financial flow(s) in industrial network	X			
Information flow(s) in industrial network		X		

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 4.13 Classification of External Option 8.3

The local government is currently creating a platform for waste exchange that will link the waste generators with waste users. An internet website is being set up to provide this platform. The textile printing company could make use of this exchange programme.

The waste coloured pastes, that can not be reused by the textile printer, are valuable waste streams that could be submitted to the waste exchange database. Approximately, 10,000 kg of coloured pastes is disposed on a landfill site annually. The average value of 1 kg of coloured paste is 3,50 ZAR; the loss of raw materials is estimated at 35,000 ZAR per year. It should be mentioned that these figures account for both the rotary and the flatscreen plant. Instead of paying for disposing the waste coloured pastes (up to 15,000 ZAR per year), the company could create an income by selling these coloured pastes to competitors or other potential users (for example the plastic industry?).

However, there is a barrier. Each coloured paste has it unique composition of pigments, binders, hardeners, fixing agents etc. The buyer of the waste coloured paste needs to know the full recipe in order to apply the coloured paste in its production process, otherwise the coloured paste is only of limited use. The recipe of the coloured paste is regarded as confidential as it based on years of experience; it gives case-study company a competitive advantage. Possible solutions to this "confidentially" problem is the signing of a confidentially agreement or only selling the coloured paste to companies that do not serve the same market as the case-study company.

The textile printer generates about 100 kg of waste plastic per week; this plastic is the wrapping of the incoming fabric. The waste plastic could also be a valuable input material to another company. This plastic is already being collected for external recycling, but it would be more efficient, in terms of energy and material use, if it could be reused without being reprocessed.

Additionally, the textile printing company could use other company's waste streams as well. Plastic and cardboard packaging can be mentioned in this regard (the textile printing company uses approximately 10,000 kg of plastic and tape annually). There may even be possibilities for the textile company to use waste coloured pastes from competitors as well.

This option is considered to be feasible. However, there are barriers of perceptions, as mentioned above, to overcome before this option can be implemented. The access fee to submit waste streams to the waste exchange database are extremely low as the local government wants to encourage industry to reduce their amount of wastes ending up on the municipal landfill sites. Once a match is found with another waste generator, the price of the waste has to be negotiated.

4.8 Network Impact Matrix versus Brainstorming Session

Table 4.14 gives a total overview of all identified improvement options and indicates whether they are identified by the network impact matrix or the brainstorming session. It also indicates which of these options were selected for a feasibility analysis and whether they were considered to be feasible or not.

Ref. no.	Identified options by industrial network approach	Internal or external option?	Identified by brain-storming session?	Identified by network impact matrix?	Selected for feasibility analysis	Estimated feasible for company?
1.	**Energy**					
1.1	Usage of alternative energy for heating processes.	Internal	Yes	No	No	N.A.
2.	**Environmental management**					
2.1	Better utilisation of the services offered by support organisations regarding.	External	Yes	No	Yes	Yes
2.2	Utilisation of available environmental incentive schemes from the government.	External	Yes	No	Yes	No
2.3	Optimisation of handling and washing requirements of clothing.	External	Yes	Yes	Yes	No
3.	**Inspection/control/maintenance**					
N.A.	No identified improvement options for "Inspection / control / maintenance".	N.A.	N.A.	N.A.	N.A.	N.A.
4.	**Packaging**					
4.1	Improvement of packaging, transport standards and efficiency within client-part of textile company's network.	External	No	Yes	Yes	Yes
4.2	Reuse of plastic foil to wrap printed fabric instead of using new plastic foil.	Internal	Yes	Yes	Yes	Yes
4.3	Reduction of environmental impact of packaging of supplied chemicals.	Internal	No	Yes	Yes	Yes
5.	**Process optimisation**					
5.1	Application of JIT-principle at textile printing company.	External	Yes	No	Yes	No
5.2	Replacement of currently used hazardous process chemicals by available less hazardous alternatives.	Internal	Yes	Yes	Yes	Yes
6.	**Product design**					
6.1	Obtain approval for the EU Eco-labeling scheme.	External	Yes	Yes	Yes	No
7.	**Transport**					
N.A.	included in option 4.1	N.A.	N.A.	N.A.	N.A.	N.A.
8.	**Wastes**					
8.1	Assessment of general waste for valuable, recyclable components.	Internal	Yes	Yes	No	N.A.
8.2	Participation of waste exchange programme.	External	Yes	Yes	Yes	Yes

Table 4.14 Overview of Results of Network Impact Matrix and Brainstorming Session

Based on the table, shown above, Table 4.15 can be generated. This table evaluates the extent to which the network impact matrix and the brainstorming session were able to identify (feasible) options.

	Number of improvement options								
	Identified			Selected for feasibility analysis			Estimated feasible for the company		
	Internal option	External option	Total	Internal option	External option	Total	Internal option	External option	Total
Only by network impact matrix	1	1	2	1	1	2	1	1	2
Only by brainstorming session	1	3	4	0	3	3	0	1	1
Identified by both the network impact matrix & brainstorming session	3	3	6	2	3	5	2	1	3
Total	5	7	12	3	7	10	3	3	6

Table 4.15 Analysis of Network Impact Matrix and Brainstorming Session

The network impact matrix and the brainstorming session identified two and four unique improvement options respectively. An additional six improvement options were identified by both the network impact matrix and the brainstorming session.

The aim of the industrial network assessment was to identify eco-efficient improvement options in the industrial network of the textile printing company. The effectiveness of both the network impact matrix and the brainstorming session are, therefore, determined by the number of external options that are considered feasible for the textile company.

The brainstorming session initially identified more external improvement options than the network impact matrix. However, as shown in Table 4.15, both the network impact matrix and the brainstorming session identified only one feasible external option, which was not identified by the other technique. One other external option was identified by both the network impact matrix and the brainstorming session.

4.9 Conclusions

Although efforts were made to minimise the company's wastes and reduce the water consumption, a full waste minimisation assessment was not carried out at the textile printing company. It was therefore not possible to compare the results of the network assessment with those from a waste minimisation assessment.

The effectiveness of the methodology developed is determined by the number of identified external improvement options that are estimated feasible for the textile printing company. The quantity and quality of the internal improvement options are not viable criteria to determine the effectiveness or value of the industrial network approach because these options would most probably be covered by a waste minimisation assessment.

The industrial network assessment, conducted at the textile printing company initially identified seven external improvement options of which three options were estimated feasible for the textile printing company. Two external options, estimated to be non-feasible for the textile printing company, were considered feasible for the one or several of the company's network partners.

The reasons why four external improvement options were not found feasible for the case-study company are:

- the case-study company does not benefit from the option (option 2.2/option 2.3);
- extensive effort is required to implement the option (option 2.2/option 5.1/option 6.1);
- significant investments have to be done before the option generates financial benefit (option 6.1);
- the option is not suitable for the process characteristics of the case-study company (option 5.1).

One of the three feasible external improvement options was covered by the network impact matrix, one option only by the brainstorming session and another by both the network impact matrix and the brainstorming session. For the textile printing company, both techniques added value to the developed methodology and its experiments.

The total number of feasible improvement options (six in total), identified by the industrial network assessment, is regarded as low. It can therefore be questioned whether it is worthwhile for an SME to invest a considerable amount of time and effort into carrying out the full industrial network procedure as developed and described in this thesis. This issue will be further addressed in Chapter 6 in which the developed methodology is evaluated and discussed in detail.

5 Application of the Method to a Small Enterprise in the Metal Finishing Sector

5.1 Introduction

This chapter describes and evaluates the experimental results of the industrial network assessment conducted at a metal finishing company.

A powder coating company participating in the research project "An Industrial Symbiosis View of SMEs" was selected for testing the developed industrial network assessment on a metal finishing company. No significant changes were applied in the methodology after testing the industrial network assessment on the textile printing company.

A full waste minimisation assessment had previously been conducted at the powder coating company between November 1997 and March 2000. The developed industrial network assessment was tested on the metal finishing company between December 1999 and April 2000.

The procedure followed for the metal finishing company was somewhat different from the industrial network assessment conducted at the textile company. During the experimental work with the metal finishing company, the brainstorming session was conducted after completing the network impact matrix. At the textile company, the brainstorming session was conducted first. Chapter 7 "Discussion and Conclusions" will discuss the optimum sequence of both techniques in detail.

In addition, a full waste minimisation assessment was not completed for the textile company. For this reason, it was not possible to compare the results and experiences of the industrial network assessment with those of a completed waste minimisation assessment.

It is stipulated in Chapter 3 that the industrial network assessment can identify additional improvement options for the powder coater which were not identified by the conducted waste minimisation assessment at this company.

The following two sections of this chapter give a general overview of the South African metal finishing industry and the powder company respectively, in order to understand the terminology used and the experimental results. After this general overview, the experimental results of the conducted waste minimisation and industrial network assessment at the powder coating company are discussed in order to determine if the developed network approach is a valid tool to be conducted at an SME in addition to a waste minimisation assessment.

5.2 The South African Metal Finishing Industry

5.2.1 *A Brief Description of the Metal Finishing Processes*

The metal finishing industry is a highly diverse and flexible industry supplying to many different industries. Products that have undergone surface finishing can be found almost anywhere. Some examples of the major industries that depend upon metal finishing in the manufacturing of their products are:

- automotive
- aerospace
- commercial aviation
- communication
- computer equipment
- construction hardware
- furniture
- household appliances and accessories
- jewellery
- motorcycles / bicycles
- oil drilling equipment
- steel mill products

- defense
- electric hardware
- tools and dyes

Metal finishing operations include metal cleaning, metal depositions and many finishing operations. Solvents and surfactants are used for cleaning operations, acids and bases for etching, and solutions of metal salts and other compounds for electroplating [OECA, 1998].

Surface finishing / metal finishing provides protection for the base material and/or changes the surface of the base material to create any one or some of the following desirable characteristics:

- improved appearance
- corrosion resistance
- abrasion resistance
- wear resistance
- improved lubricity
- improved decorative appearance
- improved solderability
- light reflectivity
- improved electrical properties
- temperature resistance
- non-toxicity

Heat, chemical and mechanical processes are mostly used in the metal finishing industry to achieve specific mechanical requirements and surface characteristics. Which technique is used depends on the end use of the metal.

Three process stages can be distinguished generally in the metal finishing industry. Each stage of processing involves one or more baths that contain reagents designed to complete a certain step in the metal finishing process. *These three stages are:*

- *surface preparation:* the surface of the work-piece is cleaned in preparation for treatment; detergents, solvents, caustics and other media are commonly used in this stage, and the work-piece is then rinsed.
- *surface treatment:* this stage involves the actual modification of the work-piece surface, such as plating.
- *post treatment:* the work piece, having been treated, is rinsed and subject to further finishing operations, such as colouring or anti-corrosion treatment.

5.2.2 Environmental Aspects of Metal Finishing Processes

The U.S. EPA has identified the metal finishing industry as one of the most significant contributors to environmental pollution and this is probably the case throughout most of the world [Hinton, 1991]. The sector has been identified as the 4th most polluting industry in South Africa (expressed in hazardous waste per unit of GDP) [EMG, 1993].

The most common materials used by metal finishers, such as chromium, cadmium, zinc, lead, nickel and many volatile organic compounds are regarded as highly toxic or serious pollutants and a high quantity of these pollutants are discharged to the environment [Hinton, 1991].

The metal finishing industry relies heavily on the presence of fresh water for rinsing and bath make-up, and a high volume of wastewater stems from inefficient use of fresh water and chemicals [Meer v.d., 1998]. Electroplating, anodising and phosphating are the most water-intensive processes.

Rinse operations also uses large quantities of water to remove residues of cleaning or plating chemicals. Most of this water is discharged as wastewater contaminated with heavy metals, organics, acid and caustic chemicals. Conventional wastewater facilities can not deal with this wastewater because the biological treatment systems are not suitable for the heavy metals contained in the waste [EMG, 1993].

A significant amount of the input materials and chemicals used for metal finishing processes, and hence the generated wastes, can be considered as hazardous. This hazardous nature concerns the flammability and toxicity of solvents and other metals used in plating operations, and the reactivity and corrosivity of acid and alkali solutions.

Physical, chemical and electrochemical processes are all used to finish metal work-pieces. The physical processes used in the metal finishing industry do not generate as much waste as the chemical and electroplating operations.

5.2.3 Support Organisations in the South African Metal Finishing Industry

An institutional framework for the South African metal finishing industry is incorporated in Appendix K. For each support organisation, a short summary of their services is given. The framework gives an indication of which organisations can support SMEs in the metal finishing sector in improving their environmental and economic performance.

The following organisations are included in this overview:
- National Association of Automobile Component & Allied Manufacturers (NAACAM)
- National Association of Automobile Manufacturers South Africa (NAAMSA)
- Association of Architectural Aluminium Manufacturers (AAAMSA)
- Aluminium Federation South Africa (AFSA)
- Motor Industry Training Board (MITB)
- Steel and Engineering Industries Federation of South Africa (SEIFSA)
- National Union of Metalworkers South Africa (NUMSA)

5.2.4 A Brief Economic Review of the South African Metal Finishing Industry [Naumann, 2000b]

Many companies in the metal finishing industry are small and independent job shops, referred as independent metal finishers. Large companies which have included metal finishing processes into their overall production line are referred as "captive" metal finishers. Both segments have parallel ties with their suppliers and customers. The captive metal finishers seem to be more specialised in their operations, because they often only process a specific kind of product for specific customer market. The independent metal finishers, on the other hand, often serve a diverse range of customers with different requirements [P2IRIS, 1997].

Various industry sectors include metal finishing processes as the metal finishing industry is a process/service rather than a product/output industry. Therefore it is difficult to determine the exact size of this sector and the impact of metal finishing industry on the South African economy.

The majority of the metal finishing companies are located in Gauteng, Cape Town and Durban. According to Statistics South Africa [2000], the number of metal finishing enterprises (job-shops) in South Africa is approximately 250; this is roughly 1% of the total manufacturing enterprises.

A recent survey of 216 metal-finishing enterprises in South Africa, conducted by Jänisch [2000], found that most companies were involved in electroplating (42%), followed by powder coating (28%), wet painting (22%), phosphating (18%) and hot-dip coating / galvanising (14%). While this survey may not include all enterprises involved in metal-finishing, it nonetheless gives an indication of the distribution of processes used in the industry.

The employment opportunities for job-shops (independent metal finishers) have decreased significantly over the last years. The average wage for employers in the metal finishing industry is below the wage average of the manufacturing sector, but has remained reasonably constant the last years. The reason can be found in the low skills requirements for production staff.

The prices of raw materials used in the metal finishing sector (e.g. zinc, aluminium and nickel) depend largely on the world prices of these metals and international currency fluctuations. The sector also uses a significant amount of imported process chemicals the price of which also depend on the foreign exchange rates. The negative development of the exchange rate of the South African Rand has put pressure on the prices of the raw materials and imported chemicals.

During the last decade, a significant decline of the output of the metal finishing industry took place. This can partly be explained by the difficulties faced by SMEs as most companies in the metal finishing sector are SMEs.

5.3 Description of the Metal Finishing Company

5.3.1 General Information

The metal finishing company is a small-scale powder coater which employs about 25 people. The core business of the company is the application of a protective powder coating on a variety of aluminium parts from its customers, mainly window and door frames.

The company was founded as an offshoot of a related company about 10 years ago. The production plant operates approximately 235 days/year, with 2 shifts per day. The building market tends to have much influence on the variability of the work.

The organisational structure of the powder coater is flat. The majority of the employees are involved in the production process.

The production process and the associated machinery and equipment have not undergone significant changes since the establishment of the company. Nevertheless, innovative measures were taken; these include the use of high quality powder coatings and the implementation of an SABS-certified quality management system. Improved process control and better traceability of the powder paint are advantages of the implemented quality system.

Almost all clients of the company are locally based. The competition comes from three locally based powder coaters. Despite their small size, their market share is still approximately one third.

The powder coating company is interested in forming alliances with companies or institutions who can provide any kind of expertise beneficial to the company. There are strong links between the powder coater and their suppliers of powder coatings and process chemicals due to the limited in-house technical expertise.

Financial considerations and the limited in-house technical expertise are the main constraints to implement cleaner production practices in their company. The SABS certified management system can also be seen as a constraint for implementing cleaner production measures due to the reduced flexibility of the company regarding product or process changes.

5.3.2 Production Process [Jänisch, 1999]

The process can be divided into the following steps:

- pre-treatment
- powder coating
- oven curing

The purpose of the pre-treatment process is to clean and prepare the surface of the aluminium product in order to enable a good coating and attachment of the powder paint. A manually operated crane immerses the large aluminium products in the baths. An immersion basket, which is hung onto the crane, is used to immerse the small products in the baths. The small parts are separated by aluminium strips and tied down with nylon. The capacity of each tank is approximately 3500 to 4000 litre. The pre-treatment process consists of 9 process steps.

- Degreasing to remove oil and grease from work pieces prior to etching.
- Etching to remove thin aluminium oxide layer and create a rough surface for easier chromate coating.
- Rinsing to remove etching chemicals prior to de-smutting.
- De-smutting to remove smut formed on aluminium surface during etching.
- Rinsing to remove acid from work piece before chromating.
- Chromate conversion to convert the aluminium to a corrosion resistant surface that more easily accepts and bonds to powder coating.
- Rinsing to remove the chromate conversion chemicals prior to passivation.
- Passivation to provide a protective seal for the prevention of rust.
- Drying the pre-treated parts prior to painting.

The pre-treated aluminium products are sprayed with powder paints. Four separate spray booths are used to allow easy paint colour changes. Wire is used to suspend the aluminium pieces which are fed through the spray booth manually. Skilled operators are responsible for spraying the paint on the product by using electrostatic spray guns. An extraction system sucks up the over-sprayed powder inside the booth and a cyclone separates the powder contained in the air stream.

The company uses mainly polyester resins and epoxy powder paints. Each powder painted batch is tested for quality reasons by using test strips. This is a requirement of the SABS quality scheme.

After the coating of the aluminium, the product is then cured by baking it in an oven which results in melt-flowing of the powder. LP gas is used to heat up the two ovens to 200 °C.

5.3.3 Environmental Profile

As a result of the pre-assessment phase of the waste minimisation, Jänisch [2000] has reported the following concerns on the environmental profile of the operation:

Water use

Water is used as a solvent in the pre-treatment baths. The use of water is high mainly due the overflow of the rinse tanks in the pre-treatment process. Water is added to the rinse baths for evaporation replacement and to refill the baths after discharge of their contents to the sewer. Domestic requirements and cleaning of the pre-treatment tanks also makes up a significant part of the total water consumption at the powder coating company.

Effluent water

Contaminated rinse water is discharged continually throughout the day shift. This water meets the total chromium specification for discharge to sewer. A hexavalent chromium specification does not exist, but the concentration is significantly higher than the level of 0.05 mg/L called for by national guidelines [DWAF, 1998].

At the end of each week, the rinse baths are disposed into the sewer and refilled. The passivation solution is disposed at the same time as the rinse baths in order to dilute this solution.

The spent acidic de-smutting solution and alkaline degreasing solution are disposed into the sewer at the same time so that these solutions can neutralise each other. The emulsified oil in the degreasing solution is not removed before disposal.

Twice a year, the etching bath is renewed. The etching solution is separated from the generated sludge (e.g. powder paint) through settling. The settled sludge is collected by a waste treatment company. The spent etching solution is treated with sulphuric acid in order to precipitate the aluminium in solution before disposing it into the sewer.

The spent chromate bath is also disposed into the sewer, but is treated to convert the chrome(VI) to chrome(III) which precipitates and is removed as a sludge, sent at a significant cost to a hazardous waste landfill.

The wastewater of the powder coating company contains chromium(VI), aluminium, and fluoride. The chromium(VI) content in the effluent is over the regulated limits whilst there are no limits for aluminium and fluoride.

<u>Hazardous waste</u>

The company's hazardous waste consists of the etch bath sludge and chromate sludge which are generated during the precipitation process of respectively the etching bath and the chromate conversion bath. These sludges are collected by a waste treatment company in order to be disposed on a landfill site for hazardous wastes.

<u>General industrial waste</u>

The general industrial waste consists mainly of packaging waste and waste powder. A significant amount of waste packaging, mainly paper and plastic, is generated during the unwrapping of supplied aluminium products which have to be powder coated. Powder coating which can not be reused is baked in the oven and then disposed as general waste. The spent powder is not considered hazardous. Domestic waste from the kitchen and offices is also part of this category of waste. The general industrial waste is collected by a waste company to be disposed on a landfill site.

<u>Energy use</u>

The heating of the pre-treatment baths, air conditioning, the extraction fans of the spray booths and the spray guns are electricity intensive processes. The circulation fans of the oven and air compressors also use a significant amount of electricity.

Five gas burners heat up the curing ovens. The curing of the powder paint is a very energy intensive process step.

<u>Air emissions</u>

The coating powder is not considered as hazardous but as an irritant in the working area. Spent powder is emitted to the atmosphere which causes fine layers of powder to settle on walls and cars outside.

5.4 Conducted Waste Minimisation Assessment

Before the industrial network assessment was conducted, the powder coater completed a waste minimisation assessment which was facilitated by C. Jänisch, a Masters student in Chemical

Engineering. The waste minimisation assessment was also conducted in the framework of the research project "Industrial Symbiosis View of SMEs: Targeting Greater Eco-efficiency" of the University of Cape Town.

This section is based on the research work of C. Jänisch [2000] and gives an overview of the results of the conducted waste minimisation exercise in order to evaluate if the industrial network approach can identify additional improvement options which were not identified by the waste minimisation assessment. The waste minimisation procedure, developed by the USEPA and described in the literature review (Chapter 2), was followed.

A summary of the results of the conducted waste minimisation assessment at the powder coating company is given in Appendix L.

5.4.1 Selected Focus Areas for Waste Minimisation

Four focus areas were selected during the pre-assessment phase, these included the chromium-containing effluents, the wasted powder paint and the rinsing system.

The chrome-containing effluents were selected as focus areas because chromium(VI) is highly toxic and carcinogenic. Although currently discharged without treatment, it is likely that they would soon require expensive waste treatment and disposal on a hazardous waste landfill.

The decision to select the wasted powder paint as a focus area for waste minimisation was based on the fact that 10% of the used paint is lost due to overspray, inefficient application and recovery, leaks and inefficient color changes. The powder paint consumption has increased significantly over the last years which is mainly due to the high paint wastage.

The rinsing system was selected as a focus area because the four rinse baths are responsible for a large part of the water consumption. It was estimated that up to 50% of the pre-treatment chemicals end up in the wastewater. A closed-loop system to treat and reuse the water would be preferred.

5.4.2 Results of Assessment of the Focus Areas

5.4.2.1 *Chromium in Effluents*

Hexavelent chromium in the wastewater is as result of chromate use both in the conversion and the passivation baths. Jänisch [2000] thus firstly applied the cleaner production technique of input material substitution.

Jänisch investigated all chrome-free products for its application at the powder coating company. The findings of this investigation were that the majority of these products are not available in South Africa, only one chrome-free product could be supplied in South Africa. Conveniently, the current supplier of the powder coater could supply the available product. Based on experiences in Europe, the product has a proven performance.

The chrome-free product was successfully tested at the powder coating company and the costs were calculated as equivalent to the current chromate conversion system.

There is one constraint regarding the implementation of the chrome-free product. As mentioned in the previous sections, the powder coating company has a SABS-certified quality system. In order to obtain and maintain this certificate, the powder paint supplier has to guarantee the quality of the paint for 15 years. The powder paint supplier will only give this guarantee if the chrome-free pre-treatment chemicals, used prior to the powder paint process, are approved by Qualicoat, an international organisation which supports quality labels for all kind of coatings.

The available chrome-free product is not yet approved by Qualicoat. In order to implement this chrome-free product, approval from Qualicoat has to be obtained.

It is interesting to note that the option resulting from the application of waste minimisation techniques has a strong "networking" character. Further, Jänisch also reported significant difficulties with the application of the waste minimisation approach in this regard. The industrial network assessment will therefore follow up on this option.

5.4.2.2 Wasted Powder Paint

It was investigated that the largest part of the wasted powder paint is generated during the application of the powder on the aluminium product. Paint is lost due to overspray, overlaps on parts, cleaning of the paint equipment and colour changes.

During the assessment, improvements were identified to reduce the paint wastage during the powder paint application.

The skills of the operators could be improved by giving them continuous training. Input from the workers, staff members and suppliers of powder paint and its related products and equipment was required to increase the effectiveness of the training.

The powder application equipment employed by the powder coater is dated. This equipment needs to be modified and upgraded in the (near) future. As long as this equipment is not renewed, the application and recovery equipment has to be properly set up and maintained. A control and maintenance program, which is well structured and implemented, could achieve this.

The estimation is that the powder paint wastage can be reduced by half, which represents approximately 5% of the total paint purchases.

5.4.2.3 Water Consumption and Rinsing

Approximately 80% of the water usage is taken up by the rinse baths which cost the powder coater about ten thousand ZAR per year. Possibilities to reduce the water consumption include the installation of a closed-loop water system and the reduction of the drag-out during the pre-treatment process. It would perhaps also be possible to decrease the rinsing requirements for a rinse bath by lowering the concentration of the chrome-free chemical solution.

If the powder coating company decides to change to a chrome-free chemicals, the need for a closed-loop (waste)water system will be reduced accordingly. The reduction of drag-out would also favor the wastewater treatment requirements. Due to the low water costs, the pay-back period of the investment in a closed-loop (waste)water system is far too long to be economically feasible. Besides the investment costs, the system will generate a sludge which will have significant disposal costs. The option is expected to become more feasible in the future when the regulated effluent requirement become more stringent and the water tariffs are increased.

At the time of writing this thesis, experiments were still being done on drag-out reduction and optimisation of the rinse water flow-rate.

5.5 Conducted Experiments with the Industrial Network Approach at the Powder Coating Company

This section and the following sections of this chapter discuss the experiments and results of the developed industrial network approach at the powder coating company. The evaluation of the developed methodology itself is outlined in Chapter 6.

The author of this thesis facilitated the experiments and was therefore responsible for the co-ordination and analysis of the results of the conducted experiments.

The inventory phase consisted of mapping the industrial network of the powder coating company. This exercise was done over a time period of two weeks during which several meetings were held with the managing director of the company in order to complete the network mapping worksheets and discuss the mapped network. The full-size mapped network of the powder coating company can be found in Appendix M.

As outlined in Chapter 3, two tools are proposed to identify eco-efficient improvements in the industrial network of a company; namely a network brainstorming session and a network impact matrix. At the powder coater, the network impact matrix was conducted first. The network brainstorming sessions were carried out once the network impact matrix was completed.

The facilitator of the industrial network assessment conducted the network impact matrix over a time-period of 2 months. Company staff and network partners of the powder coater were contacted to provide missing data in order to complete the network impact matrix successfully. The resulting network impact matrix is included in Appendix P.

The network brainstorming session was led by the facilitator and done with the company's managing director. Two sessions, eachof approximately one hour duration, were necessary to go through the network brainstorming checklist. The completed checklist can be found in Appendix O.

The potential improvements, identified by the network impact matrix and network brainstorming session, were then summarised and discussed with the managing director of the company in order to select the options with the highest potential to be successful. It is not viable, time-wise, to conduct a feasibility analysis on all identified options. One meeting of approximately 2 hours was required to discuss the identified options and make a selection of the potentially most feasible options.

The feasibility analysis included an environmental, economic, technical and social evaluation on the selected improvement options. The feasibility study was conducted by the facilitator of the industrial network assessment with assistance from company staff, network partners of the powder coating company and industry specialists. It is estimated that the facilitator spent ten full working days on the feasibility analysis of the selected improvement options.

5.6 Description of the Industrial Network of the Powder Coating Company

The first step within the procedure for the industrial network assessment consists of mapping the company's industrial network. The full-size mapped network of the powder coating company can be found in Appendix M. Each section of the industrial network is discussed separately in the following subsections.

5.6.1 Shareholders

The powder coating company is owned by two local shareholders. One of the shareholders is the managing director of the company. All major decisions concerning the production (plant) are made by the managing director and the production director.

5.6.2 Suppliers

The following product categories are supplied to the powder coating company:
- process bath chemicals
- powder coating and paint
- gas / fuel / oil
- packaging
- tools / machinery

The relationship with the suppliers of the process bath chemicals and the powder coating can be described as very open and supportive. There is interactive contact between the powder coating company and these suppliers. There is even co-operation between the suppliers of process baths chemicals and powder coating. These suppliers update the powder coater with information regarding new products and technologies, and provide good after sales services (sampling, queries etc.). The powder coater is to a large extent dependant on the expertise of the suppliers of the process bath chemicals and the powder paint. These suppliers are large national and international companies.

The relationship with suppliers of the other product categories can be described as an order-pay relationship without personal contact. These suppliers are all local and almost all small sized companies.

5.6.3 Clients

Most clients of the powder coating company are local companies, a small percentage of the clients are companies outside the Western Cape. The powder coater does not export products.

The clients of the powder coater are manufacturers of aluminium products, such as office partitions or doors/windows/shopfronts. The second tier clients are financial institutions, property developers and retailers.

The collection and delivery of aluminium products is done by the transport vehicles of the powder coating company. If an order is urgent, collection and delivery is done by the clients (normally also small companies)

The communications between the powder coating company and its clients concern price, delivery, time planning and ordering of products. Environmental issues are not discussed during the communication between the powder coating company and its clients.

The powder coater does not depend on a few major clients for his profitability. Many different clients make up the order pocket.

5.6.4 Competitors

The powder coating company has three major competitors which compete on the local market for powder coated architectural aluminium. Two of the three competitors are local companies and one is a company outside the Cape Town area.

A strength of the powder coater is that it is certified by the SABS for powdered coated architectural aluminium which proves that the product quality is guaranteed for at least 15 years. A weakness is that the powder coating company does not have an in-house anodising and extruding process.

The powder coater and its competitors supply the same clients. Competition is price, quality and delivery-time driven. Good environmental performance of a powder coater does not seem to give a company a competitive advantage.

5.6.5 *Utility Providing Organisations*

The local government provides the powder coating company with water and electricity. Eskom is the generator of electricity.

There is barely no personal contact between the local government and the powder coating company. The relationship is based on payment of the water and electricity bills.

5.6.6 *Waste Treatment and Recycling Companies*

All waste treatment companies servicing the powder coater are based locally. The hazardous solid chemicals (aluminium and chrome sludge) are collected by a waste treatment company to be disposed on a landfill site. General industrial waste (refuse and powder waste) is collected by the waste services of the local government to be disposed on one of the government owned landfill sites in the Cape Town area. The scrap aluminium is collected by local scrap dealers for recycling. The scrap value of aluminium is very high, about 10 Rand per kilogram. A very large part of the waste streams of the powder coater ends up on landfill sites.

The personal contact between the powder coating company and the waste treatment / recycling companies is very low. The only contact that takes place is setting an appointment for collection of the waste and the payment of (or by) the waste treatment company.

5.6.7 *Support Organisations*

The powder coating company is certified by the scheme "Organic powder coatings for external architectural aluminium" of the South African Bureau of Standards (SABS), unlike its competitors. The company is audited by the SABS annually. The quality system increases costs through process control and tracking of the powder paint, but quality per se does not necessarily benefit the marketability of the company's product.

Most of the employees of the powder coater are members of the employee organisation NUMSA. NUMSA stands for National Union of Metal Workers of South Africa and is part of the umbrella organisation for trade unions COSATU (Congress of South African Trade Unions). The powder coating company is not affiliated to an employer organisation.

The powder coating company is a member of AAMSA (Association of Architectural Aluminium Manufacturers of South Africa) and AFSA (Aluminium Federation of South Africa). The institutions provide the powder coater with information regarding the sales figures, new technology, and future prospects in the (architectural) aluminium industry.

5.6.8 Government and Community Organisations

Effluent samples are taken irregularly by the local government. The powder coater is fined if the effluent sample exceeds the regulated requirements. The fine will be added to the water consumption bill.

The powder coater sponsors a soccer team and occasionally provides loans for its employees. The policy is that sponsoring must always be linked or beneficial to employees of the powder coating company.

5.6.9 Maintenance

The powder coating company only consults a maintenance company if the repair or maintenance can not be done in-house. All maintenance companies are based locally.

The repair / maintenance can concern:
- the production plant
- plumbing
- electrical equipment
- lift/carry equipment

The powder coater does not depend on a specific maintenance company for its repair or maintenance, although it aims to work with the maintenance companies.

5.7 Evaluation of Results of Industrial Network Assessment

5.7.1 Overview of Results

Table 5.1 gives an overview of the potential improvement options generated by the industrial network assessment which were not identified by the waste minimisation assessment. The list in Table 5.1 includes both feasible and non-feasible options. It has to be mentioned that option 5.2 was a follow-up on an option identified by the waste minimisation assessment and does therefore not add value to the conducted industrial network assessment. However, this option will be discussed in this thesis as this option has strong networking characteristics.

Each identified option was classified as an internal or an external improvement option. The difference concerns the extent of the economic, technical and social impact of the improvement options. The environmental impact is, by definition, outside the company's physical boundaries. An internal improvement can be defined as an improvement option which "only" has an economic, technical and social impact within the company's physical boundaries. An external improvement option can be defined as an improvement option which has an economic, technical and social impact in- and outside the company's physical boundaries.

Ref. no.	Additional improvement options identified by industrial network approach	Internal or external improvement option?
1.	**Energy**	
1.1	Utilisation of waste hot air from curing oven.	Internal
1.2	Usage of solar energy to heat-up the process baths.	Internal
1.3	Insulation of pre-treatment tanks and curing ovens.	Internal
1.4	Installation of timer for (de-)activating the process baths.	Internal

Ref. no.	Additional improvement options identified by industrial network approach	Internal or external improvement option?
1.5	Installation of infra-red meter to determine optimum curing time.	Internal
1.6	Prevention of heat losses during (un)loading of the products in curing oven.	Internal
2.	**Environmental management**	
2.1	Promotion of cleaner production practices in SABS-schemes.	External
3.	**Inspection / control / maintenance**	
3.1	Implementation of procedure to test the incoming products on quality criteria.	Internal
4.	**Packaging**	
4.1	Better utilisation of supplied chemicals.	Internal
4.2	Installation of waste paper/plastic container	Internal
4.3	Usage of reusable packaging system to wrap incoming and outgoing products.	External
5.	**Process optimisation**	
5.1	Extension of life-span of etching bath.	Internal
5.2	Approval of chrome-free pre-treatment chemical from Qualicoat.	External
5.3	Elimination of de-smutting process step.	Internal
5.4	Replace the TGIC-hardener in powder coating.	External
5.5	Expand business by investment in a blasting machine.	External
6.	**Product design**	
6.1	No identified improvement options for "Product Design".	N.A.
7.	**Transport**	
7.1	No identified improvement options for "Transport".	N.A.
8.	**Wastes**	
8.1	Participation in waste exchange programme.	External
8.2	Re-winning of chrome and aluminium out of the generated sludges.	Internal

Table 5.1 Overview of Results of Industrial Network Assessment

5.7.2 Screening of Identified Options

Some of the generated improvement options should have been identified by the waste minimisation assessment conducted prior to the industrial network assessment. Table 5.2 evaluates why the improvement options were not identified by the waste minimisation assessment.

An option might not have been identified because the option is not covered by the waste minimisation methodology. The selection of a limited number of focus areas during the pre-assessment phase of the waste minimisation assessment can also be a reason why an option was not identified by the waste minimisation approach.

In the following subsections, the internal and external improvement options are evaluated separately.

Ref. no.	Additional improvement options identified by industrial network assessment	Why not identified by WM-assessment?
Internal improvement options:		
1.1	Utilisation of hot air from curing oven.	Not selected as focus area
1.2	Usage of solar energy to heat-up the process baths.	Not selected as focus area

Ref. no.	Additional improvement options identified by industrial network assessment	Why not identified by WM-assessment?
1.3	Insulation of pre-treatment tanks and ovens.	Not selected as focus area
1.4	Installation of timer for (de-)activating the process baths.	Not selected as focus area
1.5	Installation of infra-red meter to determine optimum curing time.	Not selected as focus area
1.6	Prevention of heat losses during (un)loading of the products in curing oven.	Not selected as focus area
3.1	Implementation of procedure to test incoming products on quality criteria.	Outside scope of waste minimisation methodology
4.1	Better utilisation of supplied chemicals.	Outside scope of waste minimisation methodology
4.2	Installation of waste paper/plastic container	Outside scope of waste minimisation methodology
5.1	Extension of life-span of etching bath.	Not selected as focus area
5.3	Elimination of de-smutting process step.	Not selected as focus area
8.2	Re-winning of chrome and aluminium out of generated sludges.	Outside scope of waste minimisation methodology
External improvement options:		
2.1	Promotion of cleaner production practices in SABS-schemes.	Outside scope of waste minimisation methodology
4.3	Usage of reusable packaging system to wrap incoming and outgoing products.	Outside scope of waste minimisation methodology
5.2	Approval of chrome-free pre-treatment chemical.	Outside scope of waste minimisation methodology
5.4	Replace the TGIC-hardener in powder coating.	Outside scope of waste minimisation methodology
5.5	Expand business by investment in blasting machine.	Outside scope of waste minimisation methodology
8.1	Participation in waste exchange programme.	Outside scope of waste minimisation methodology

Table 5.2 Screening of the Internal and External Improvement Options

5.7.3 *Evaluation of Internal Options – Not identified by Waste Minimisation Due to Selection of Focus Areas*

As shown in Table 5.2, eight out of the twelve identified options were not identified by the waste minimisation assessment, prior to the industrial network assessment, due to the selection of a limited number of focus areas.

Table 5.3 gives an overview of which options were selected for a feasibility analysis and were estimated to be feasible. This table shows that the selection of focus areas restricts option identification and therefore eliminates potential feasible improvement options. Focus area selection should therefore be done carefully. However, as discussed in the literature review, waste minimisation is a process of continuous improvement. The options summarised in Table 5.3 would most probably be identified in the second, or even third cycle, of the waste minimisation cycle. Therefore, these options do not add value to the industrial network assessment.

Ref. no.	Internal improvement options – Unidentified due to selection of focus areas	Selected for feasibility analysis?	Estimated feasible?
1.1	Utilisation of hot air from curing oven.	Yes	Yes
1.2	Usage of solar energy to heat-up the process baths.	Yes	No
1.3	Insulation of pre-treatment tanks and ovens.	Yes	Yes
1.4	Installation of timer for (de-)activating the process baths.	Yes	No
1.5	Installation of infra-red meter to determine optimum curing time.	No	N.A.
1.6	Prevention of heat losses during (un)loading of the products in curing oven.	No	N.A.
5.1	Extension of life-span of etching bath.	Yes	No
5.3	Elimination of de-smutting process step.	No	(Yes)

Table 5.3 Options not Identified by Waste Minimisation Due to Selection of Focus Areas

During the pre-assessment phase, the process and related waste streams were assessed in detail, and from this assessment, a summary of attention areas was compiled. Focus areas for waste minimisation were then selected from these attention areas based on an evaluation of a number of criteria:

- quantity
- hazardous nature
- cost
- waste minimisation potential
- other

A point value from 0 to 5 was given to each criteria. The total score for each attention area determined whether the attention area was selected as a focus area or not. A detailed explanation of these selection criteria can be found in Appendix N.

5.7.3.1 *Attention Area: Energy*

At the powder coater, energy concerns the use of electricity and gas. Electricity is used to heat up the process baths, the cyclone motors of the spray booth and the spray guns. The circulation fans of the oven and air compressors also use a significant amount of electricity. Gas is used to heat up the ovens for curing the powder paint.

Table 5.4 gives an overview of the ratings for electricity and gas. The total score of seven was not enough to select electricity or gas as a focus area for the waste minimisation assessment.

Attention area	Quantity	Hazardous nature	Cost	WM potential	Other	Total
Electricity	1	0	4	1	1	7
Gas	3	0	4	0	0	7

Table 5.4 Rating of Attention Area "Energy"

Energy was not selected as a focus area for the powder coating company; the options 1.1, 1.2, 1.3, 1.4. 1.5 and 1.6 were therefore not addressed during the assessment phase of the waste minimisation. Only two of these six options are estimated to be feasible options.

During the discussion of the energy-options for the powder coater, the idea came up to consult the support organisation "Industrelek" to assess the identified options in more detail, and to address the overall energy-efficiency of the powder coating company. Industrelek is a subdivision of ESKOM, South African main electricity generator. Their aim is to assist industrialists in utilising their energy sources as efficiently as possible and to promote the use of electricity as an energy-source.

5.7.3.2 *Attention Area: Spent Etching Bath*

Based on the rating of the evaluation criteria, shown in Table 5.5, the etching bath was not selected as a focus area for waste minimisation.

Attention area	**Quantity**	**Hazardous nature**	**Cost**	**WM potential**	**Other**	**Total**
Spent etching bath	3	3	2	0	0	8

Table 5.5 Evaluation of Attention Area "Spent Etching Bath"

Options 5.1 "Extension of life-span of etching bath" was not selected as a focus area, and therefore, this option was not identified in the waste minimisation assessment.

The etching bath is an expensive bath due to the relatively high purchase costs of the process chemicals. During the etching process, aluminium from the processed products goes into solution. Twice a year, the etching bath is renewed. The etching solution is separated from the generated sludge (e.g. powder paint) through settling. The settled sludge is collected by a waste treatment company. The spent etching solution is treated with sulphuric acid in order to precipitate the aluminium in solution.

The clarified etching solution is currently disposed into the sewer. The improvement option concerns the reuse of this clarified etching solution in the etching bath. However, the quality of the clarified etching solution is not good enough to be reused as the clarified solution still contains aluminium in solution and also contains other contaminants.

The overall rating of the evaluation criteria "Quantity" and "Hazardous nature" indicate that there is a need for better control of the etching bath. However, the spent etching bath has not been selected as a focus area due to the low rating of the criteria "Waste minimisation potential", "Other" and "Costs". Therefore, the option to extend the life-span of the etching bath was not identified during the waste minimisation assessment..

5.7.3.3 *Attention Area: Spent De-smutting Bath*

Table 5.6 gives an overview of the ratings of the evaluation criteria for the attention area "Spent de-smutting bath".

Attention area	**Quantity**	**Hazardous nature**	**Cost**	**WM potential**	**Other**	**Total**
Spent de-smutting solution	2	1	1	0	1	5

Table 5.6 Evaluation of Attention Area "Spent De-smutting Bath"

The function of the de-smutting step is to remove the smut which is formed on the aluminium product during the etching step. It might be possible to eliminate the de-smutting process step if an alternative for the currently used etching chemical is found which does not cause the forming of smut on the aluminium surface. However, this option was not selected for a feasibility study as the substitution of the chromate conversion and passivation chemicals with chrome-free alternatives are currently being investigated. This substitution will possibly effect the etching and de-smutting process steps as well. The elimination of the de-smutting step can only be investigated when the assessment of the chromate conversion and passivation step is completed.

Options 5.3 "Elimination of de-smutting step" is obviously related to the de-smutting bath and was therefore not identified during the assessment phase of the waste minimisation assessment. The overall rating of all selection criteria for the spent de-smutting solution is low and is correctly not selected as a focus area for waste minimisation at the powder coating company.

5.7.4 Evaluation of Internal Options – Not Identified by Waste Minimisation Due to Scope of WM-Methodology

Table 5.7 shows the internal improvement options which were not identified during the waste minimisation assessment, as these options are not covered by the waste minimisation methodology.

Ref. no.	Internal improvement options – unidentified due to scope of waste minimisation procedure	Selected for feasibility analysis?	Estimated feasible?
3.1	Implementation of procedure to test incoming products on quality criteria.	Yes	Yes
4.1	Better utilisation of supplied chemicals.	Yes	Yes
4.2	Installation of waste paper/plastic container.	Yes	No
8.2	Re-winning of chrome and aluminium out of generated sludges.	No	No

Table 5.7 Options – Unidentified Due to Scope of Waste Minimisation Procedure

5.7.4.1 Option 3.1: Implementation of Procedure to Test Incoming Products on Quality Criteria

The powder coating company coats aluminium products which are directly supplied by their clients. When bad quality aluminium is powder coated, it results in poor quality coated products that have to be reprocessed which, has a negative impact on the material, energy use and the related costs. By inspecting incoming aluminium, this can be prevented.

This option is considered feasible as it only requires additional effort from staff members to inspect the incoming aluminium products, and no major investments or technical changes are required to make this option successful.

Option 3.1 concerns the waste minimisation technique "good housekeeping". However, it is felt that this option is not fully covered by the WM-methodology. The literature study (Chapter 2) revealed that the main focus of the WM-methodology is on wastes directly associated with the company's production process and its waste treatment processes. The inspection and delivery of incoming products does not seem to be the main focus during a waste minimisation assessment.

5.7.4.2 Option 4.1: Better Utilisation of Supplied Process Chemicals

Many process chemicals are supplied in plastic cans. Some of the empty cans are returned to the chemical supplier or reused internally. Empty cans from suppliers, who do not provide a take-back service, are collected by a plastic recycling company. These empty cans are still contaminated with hazardous and non-hazardous chemicals and will be rinsed by the recycling company.

The powder company can help prevent hazardous chemicals ending up in the sewer by fully emptying the plastic cans. This can done relatively easily by emptying the can upside-down above the process baths. In this way, the complete contents of the can can drip into the process bath. A (removable) rack has to be made above the bath in which the can can be placed which is a minor technical change and small financial investment.

The waste minimisation methodology "only" assesses options for which the environmental impact is directly related to the company's process. It is outside the boundaries of the WM-methodology to address environmental impacts that occur due to up- and down-stream business activities linked to the production process of a company.

5.7.4.3 *Option 4.2: Installation of Waste Paper/plastic Container*

The incoming aluminium products, received from the clients of the powder coating company, and outgoing powder coated products are wrapped in paper and plastic. All waste paper (100 kg per month) and plastic (100 kg per month) is not recycled, but is disposed as general industrial waste.

Due to the relatively small amount of waste paper and plastic, it is currently not economically feasible for the paper/plastic recycling company to install a paper/plastic container at the powder coater and empty this container for free. This is due to the current low prices for recycled paper, which is market dependent. However, it is possible for the powder coating company to collect the waste paper separately and bring it to a paper recycling container close by, or even to the paper recycling company directly.

This option concerns the fifth preferable waste management strategy, namely "Energy/material recovery". This strategy is not incorporated in the waste minimisation methodology and was therefore not identified by the waste minimisation assessment at the powder coating company.

5.7.4.4 *Option 8.2: Re-winning of Chrome and Aluminium from of Generated Sludges*

Chrome and aluminium sludges are generated by the treatment of the chromate and the etching bath respectively. These sludges are collected by a hazardous waste company which disposes them on a landfill site. The proposal evaluated was to re-win the chrome and aluminium out of the generated sludges.

A literature review revealed that this option is not considered feasible as the sludge volumes are far too low to make re-winning economically viable.

The re-winning of chrome and aluminium concerns the waste management strategy "Energy / material recovery" which is not incorporated in the waste minimisation methodology.

5.7.5 ***Evaluation of External Improvement Options***

This section discusses the external improvement options identified during the industrial network assessment at the powder coater.

Ref. no.	External improvement options	Selected for feasibility analysis?	Estimated feasible for company?	Estimated feasible in network?
2.1	Promotion of cleaner production practices in SABS schemes.	Yes	No	Yes
4.3	Usage of a reusable packaging system to wrap incoming and outgoing products.	No	N.A.	N.A.
5.2	Approval of chrome-free pre-treatment chemical by Qualicoat.	Yes	Yes	N.A.

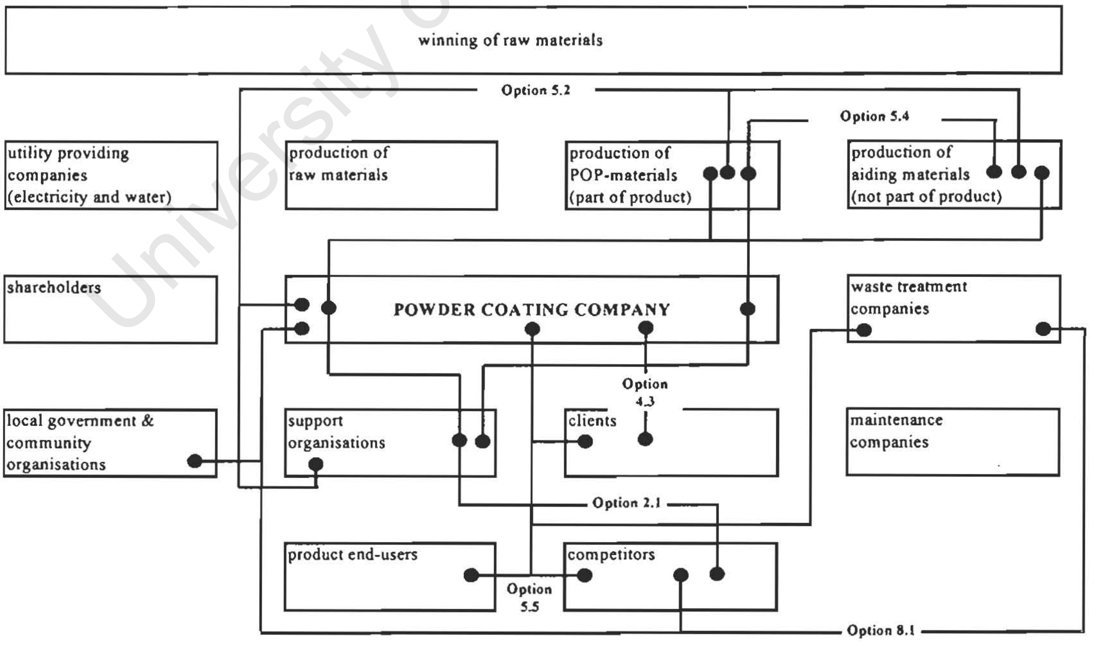
Ref. no.	External improvement options	Selected for feasibility analysis?	Estimated feasible for company?	Estimated feasible in network?
5.4	Replace the TGIC-hardener in powder coating.	Yes	No	Yes
5.5	Expand business by investment in blasting machine.	Yes	Yes	N.A.
8.1	Participation in waste exchange programme.	Yes	Yes	N.A.

Table 5.8 Evaluation of External Improvement Options

For the external options, a rough feasibility study was also carried out to estimate whether an option is environmentally, economically, technically and socially viable for implementation by the powder coating company. When an external improvement option is found not feasible for the powder coating company, it can still be a feasible option for one or more network partners of the case-study company. This is indicated in the last column of Table 5.8.

The external option "Approval of chrome-free pre-treatment chemical by Qualicoat" was not identified by the industrial network assessment, but was a follow-up on a process improvement identified by the waste minimisation assessment.

Figure 5.1 illustrates how the selected external improvement options fit into the industrial network model and which network sections should be involved for successfull implementation of the improvement option. Each option is discussed in detail in the following subsections.



List of selected external improvement options:
Option 2.1: Promotion of cleaner production practices in SABS-schemes
Option 4.3 Usage of reusable packaging system to wrap incoming and outgoing products
Option 5.2: Approval of chrome-free pre-treatment chemical from Qualicoat
Option 5.4: Replacement of TGIC-hardener in powder coating
Option 5.5: Expand business by investment in blasting machine
Option 8.1: Participation in waste exchange programme

Figure 5.1 External Improvement Options Linked with Industrial Network Model

5.7.5.1 *Option 2.1: Promotion of Cleaner Production Practices in SABS-schemes*

A classification of option 2.1 is given in Table 5.9.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session		X	N.A.	
Network impact matrix	X		Product handling by first, second and third tier clients (App. P)	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network		X		Option may indirectly improve all environmental concerns (material choice, energy use, solid / liquid / gaseous residues)
Financial flow(s) in industrial network		(X)		
Information flow(s) in industrial network	X			

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 5.9 Classification of External Option 2.1

The powder coating company is certified by the scheme "Organic powder coatings for external architectural aluminium" of the South African Bureau of Standards (SABS).

This scheme focuses mainly on the quality of powder coated products. The option evaluated was whether environmental standards or requirements could be incorporated in this SABS scheme in order to motivate powder coating companies to address quality and environmental issues related to their product and production process.

SABS schemes could incorporate qualitative and quantitative requirements regarding:
- Material choice (e.g. no use of chrome(VI) chemicals)
- Solid emissions (e.g. hazardous wastes, industrial waste)
- Liquid emissions (e.g. effluent)
- Gaseous emissions (e.g. toxicity of process bath chemicals)
- Energy use (e.g. energy efficiency)

In the SABS scheme, it is also mentioned that when a purchaser requires ongoing verification of the powder coating process, attention should be given to the powder coater's quality system. The SABS ISO9001/2/3 is mentioned in this regard. In the SABS scheme, it could also be mentioned that when a purchaser requires ongoing verification of the environmental aspects and effects of the powder coating process, attention should be given to the manufacturer's environmental management system. The ISO14001 norm could be mentioned in this regard.

It is difficult to determine the feasibility of this option as many aspects have to be taken into account, e.g. what kind of changes are made in the SABS scheme. The feasibility analysis can be assessed from two different perspectives; from the powder coating company's point of view and from a network point of view.

It can not be expected of the powder coater to take the initiative to implement this option. The option is too complicated and does not directly improve the economic and environmental performance of the powder coating company. It is more likely that the implementation of the option should be initiated by the South African Bureau of Standards itself. In this regard, an interesting question to ask would be whether the SABS would consider running an EMS for itself, which would commit it to reviewing all its standards for environmental impact.

However, the option will certainly benefit the powder coating company as the company has already conducted a waste minimisation and industrial network assessment. It is therefore expected that the powder coater will meet the "new" emission requirements of the SABS scheme. The SABS scheme will also become a stronger marketing instrument as the scheme will focus on quality and environmental aspects of the company's product and process. This will be a strong argument for exporting companies in particular to get SABS certification. With the "new" SABS scheme, a company could prove that it meets a certain environmental standard without having a fully implemented environmental management system.

5.7.5.2 *Option 4.3: Reusable Packaging System for Incoming and Outgoing Products*

A classification of option 4.3 is given in Table 5.10.

<table>
<tr><th>Option was generated by:</th><th>Yes</th><th>No</th><th colspan="2">Reference</th></tr>
<tr><td>Network brainstorming session</td><td>X</td><td></td><td colspan="2">Question 4.1 in brainstorming checklist (App. O)</td></tr>
<tr><td>Network impact matrix</td><td>X</td><td></td><td colspan="2">Product packaging and transport - to and from SME (App. P)</td></tr>
<tr><th>Options aims to optimise:</th><th>Direct *</th><th>In-direct*</th><th>No</th><th>Environmental benefits of option:</th></tr>
<tr><td>Material flow(s) in industrial network</td><td>X</td><td></td><td></td><td rowspan="3">Option will reduce material use and solid emissions</td></tr>
<tr><td>Financial flow(s) in industrial network</td><td></td><td>X</td><td></td></tr>
<tr><td>Information flow(s) in industrial network</td><td></td><td></td><td>X</td></tr>
</table>

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 5.10 Classification of External Option 4.3

All incoming aluminium products, which have to be powder coated, are wrapped in paper and plastic by the clients before being transported to the powder coater. These products are unwrapped at the powder coating company just before they are pre-treated. The waste packaging is not recycled, but disposed as general industrial waste. To protect the powder coated products during transport back to the clients, new plastic and paper is used again to wrap the products.

If a reusable packaging system can be found to protect the incoming and outgoing products, then the packaging waste would decrease dramatically. An idea for a reusable packaging system can be rubber sleeves which can be put over or wrapped around the aluminium products. The implementation of this reusable packaging system would require extensive collaboration between the powder coater and its clients as the packaging requirements of both parties have to be met.

It was the opinion of the managing director of the powder coating company that the practical feasibility of this option is low and he was therefore not interested in conducting a detailed feasibility analysis for this option.

5.7.5.3 *Option 5.2: Approval of Chrome-free Pre-treatment Chemical*

A classification of option 5.2 is given in Table 5.11.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session		X	Follow-up on waste minimisation assessment	
Network impact matrix		X		
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network		X		Option will improve material choice and reduce gaseous emissions
Financial flow(s) in industrial network			X	
Information flow(s) in industrial network	X			

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 5.11 Classification of External Option 5.2

One of the identified improvement options of the waste minimisation assessment at the powder coater, is to substitute the currently used chrome(VI) chromate conversion chemical with a chrome-free pre-treatment chemical. Chrome chemicals in the hexavalent form are regarded as highly toxic.

Due to the demands of the market for architectural aluminium, the powder coating company gives a guarantee on the powder application to its customers for a period of fifteen years. The powder coater can only give this guarantee if their powder supplier does so as well. The powder suppliers will only guarantee their paint for fifteen years if the powder coating company is certified by the SABS scheme "Organic powder coatings for external architectural aluminium". However, this SABS scheme does not cover the application of chrome-free pre-treatment chemicals. In order to control the application of chrome-free chemicals and guarantee the powder for 15 years, the powder suppliers refer to the "Qualicoat" international standard for powder coatings. This standard has approved a number of chrome-free pre-treatment chemicals.

The facilitator of the waste minimisation assessment has found a chrome-free pre-treatment chemical which was tested successfully in the production process of the powder coating company. Unfortunately, this chrome-free chemical is not officially approved by Qualicoat. The powder coater can not use this new chrome-free chemical before it is Qualicoat approved, or the powder paint supplier will not guarantee the paint for 15 years. Figure 5.2 illustrates the problem.

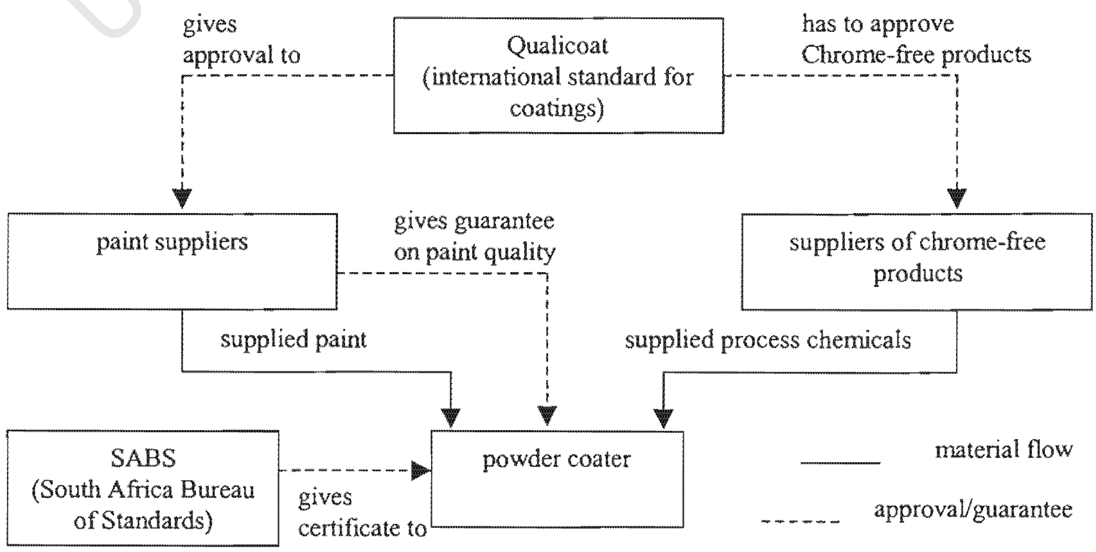


Figure 5.2 Visualisation of Quality System Constraint

The option to substitute the chrome(VI) pre-treatment chemical for a chrome-free chemical shifted from a typical waste minimisation option to a constraint in the network of the powder coating company. Therefore, this option was taken up by the industrial network assessment. It has to be mentioned that this option was not identified by the industrial network assessment itself.

The facilitator of the industrial network assessment has been in contact with the powder paint supplier in order to find out the procedure for getting approval from Qualicoat for the chrome-free chemical. It was found that the testing procedure takes approximately two years in total.

The particular chrome-free chemical has already been tested for Qualicoat approval for one year and it is expected to be officially approved by next year.

The supplier of the chrome-free pre-treatment chemical recently merged with another international chemical supplier. This merged company does supply a chrome-chemical which is already approved by Qualicoat. This chemical still needs to be assessed on costs and application in the production process of the powder coater. At the time of writing this thesis, this assessment was not yet completed.

If the already-approved chrome-free chemical is not practically feasible for the company, then the yet unapproved chrome-free chemical will be applied as soon as Qualicoat approval has been obtained.

The option of getting approval for the chrome-free pre-treatment chemical is considered to be feasible option. The testing procedure is carried out and financed fully by the supplier and the pre-treatment chemical can be applied as soon as approval from Qualicoat is obtained. Fortunately, the supplier of the chrome-free chemical already started the testing procedure. Otherwise, the option would not have been feasible time-wise.

This option shows that national and international quality standards can be a barrier for the implementation of cleaner production practices as the company can not easily and quickly substitute hazardous process chemicals for less hazardous alternatives.

5.7.5.4 *Option 5.4: Replacement of TGIC-hardener in Powder Coating*

A classification of option 5.4 is given in Table 5.12.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session		X	N.A.	
Network impact matrix	X		Product manufacturing by SME (App. P)	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network	X			Option will improve material choice and reduce gaseous emissions
Financial flow(s) in industrial network			X	
Information flow(s) in industrial network			X	

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 5.12 Classification of External Option 5.4

The powder coating company currently uses a powder paint which contains a TGIC-hardener. TGIC stands for Triglycidyl Isocyanurate and has problematic occupational health characteristics, as e.g. allergen effects. The regulation of the European Union has marked TGIC as toxic [anonymous, 1997]. TGIC can be replaced by the less hazardous alternative, Beta-hydroxyalkylamide.

The powder supplier of the powder coater can supply TGIC-free powder paints. However, according to the powder paint suppliers there are two barriers regarding the application of TGIC-free powder paint; namely quality and price.

If the applied paint thickness is higher than 20 micron, thin holes will appear in the surface of the paint due to water releases during the drying process. Additionally, the white color TGIC-free paints tend to "yellow" slightly after a period of time.

As the powder coating company has a certified quality system, the high quality requirements of the SABS scheme "Organic powder coatings for external architectural aluminium" will have to be met. Before substitution with the TGIC-hardener can take place, a considerable number of tests have to be carried out to determine if the SABS requirements are met by the TGIC-free powder paint.

The replacement of the TGIC-hardener in the powder paint is considered to be an external improvement option as considerable collaboration between the powder coater, the suppliers of powder paint and pre-treatment chemicals, and the South African Bureau of Standards would be required to successfully implement this option.

The TGIC-free powder paint is not yet produced in bulk in South Africa, but has to be produced by order. Therefore, the cost price will be slightly higher than powder paint which contains TGIC.

Based on the above mentioned barriers, the powder coating company will not substitute the currently used powder paints for TGIC-free paints. Additionally, the powder paint is not perceived as an important environmental issue by the manager director of the powder coating company. However, it might be feasible for the powder paint supplier to improve the quality of TGIC-free paints and to investigate the consumer markets for TGIC-free powder paints.

5.7.5.5 Option 5.5: Expand Business by Investment in Blasting Machine

A classification of option 5.5 is given in Table 5.13.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session	X		Question 8.4 in brainstorming checklist (App. O)	
Network impact matrix	X		Pre-manufacturing (App. P)	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network	X			Option will improve material choice and reduce liquid emissions
Financial flow(s) in industrial network	X			
Information flow(s) in industrial network			X	

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 5.13 Classification of External Option 5.5

Currently, waste aluminium products of the powder coating company are cleaned with sulphuric acid or sold as scrap aluminium to a recycling company. Sulphuric acid is considered to be a hazardous chemical.

Instead of using sulphuric acid or disposing the waste aluminium products, a blasting machine can be used to clean waste aluminium products. Such a blasting machine uses very small plastic projectiles as a blasting material. Tests showed that the blasting machine can achieve the required quality needed for the pre-treatment and powder coating process.

The blasting material is expensive, at 80 ZAR per kg. Test runs with the blasting material will determine how many times it can be reused. The purchase cost of a blasting machine is roughly 50,000 ZAR. The value of the waste products, generated by the powder coater only, is estimated to be 10,000 ZAR p.a., which is not enough to make the investment economically feasible for the powder coating company alone. This is due to the high costs of the blasting material and the blasting machine.

However, the powder coater could create a business opportunity by blasting the waste aluminium products for its clients, competitors and perhaps other network partners as well. This option becomes financially feasible if these network partners would get on-board and bring their waste products to the powder coating company.

5.7.5.6 *Option 8.1: Participation in Waste Exchange Programme*

A classification of option 8.1 is given in Table 5.14.

Option was generated by:	**Yes**	**No**	**Reference**	
Network brainstorming session	X		Question 8.2 in brainstorming checklist (App. O)	
Network impact matrix		X	N.A.	
Options aims to optimise:	**Direct ***	**In-direct***	**No**	**Environmental benefits of option:**
Material flow(s) in industrial network	X			Option will improve material choice, reduce solid and liquid emissions
Financial flow(s) in industrial network	X			
Information flow(s) in industrial network		X		

* by improvement of one flow category (direct optimisation), another flow category might be optimised as well (indirect optimisation)

Table 5.14 Classification of External Option 8.1

The local government is currently creating a platform for waste exchange to match the waste generators with waste users. An internet website is being set up to provide this platform. The powder coater could make use of this exchange programme.

Waste powder paint that can not be reused internally, the chrome and aluminium sludge, waste plastic and paper are waste streams which could be submitted to the waste exchange database. The powder coating company could possibly use other company's waste as well. Waste cardboard and plastic might be useful to the powder coater to pack powder coated products. Spent sulphuric acid, generated by another company, could perhaps be used to treat the etching bath of the powder coating company.

This external option is considered feasible. The costs to submit to the waste exchange programme are exceptionally low. Once a match is found with another waste generator, the price of the waste has to be negotiated.

5.8 Network Impact Matrix versus Brainstorming Session

Table 5.15 gives a total overview of all improvement options identified during the network assessment and whether they were identified by the network impact matrix or the brainstorming session. It is also stated which of these options were selected for a feasibility analysis and were estimated feasible.

The completed brainstorming checklist and network impact matrix of the powder coating company can be found in Appendices O and P, respectively.

Ref. no.	Additional improvement options identified by industrial network approach	Internal or external option?	Identified by network impact matrix?	Identified by brain-storming session?	Selected for feasibility analysis	Estimated feasible for company?
1.	**Energy**					
1.1	Utilisation of waste hot air from curing oven.	Internal	Yes	Yes	Yes	Yes
1.2	Usage of solar energy to heat-up the process baths.	Internal	Yes	Yes	Yes	No
1.3	Insulation of pre-treatment tanks and curing ovens.	Internal	Yes	No	Yes	Yes
1.4	Installation of timer for (de-) activating the process baths.	Internal	No	Yes	Yes	No
1.5	Installation of infra-red meter to determine optimum curing time.	Internal	No	Yes	No	N.A.
1.6	Prevention of heat losses during (un)loading of the products in curing oven.	Internal	Yes	No	No	N.A.
2.	**Environmental management**					
2.1	Promotion of cleaner production practices in SABS-schemes.	External	Yes	No	Yes	No
3.	**Inspection/control/maintenance**					
3.1	Implementation of procedure to test the incoming products on quality criteria.	Internal	No	Yes	Yes	Yes
4.	**Packaging**					
4.1	Better utilisation of supplied chemicals.	Internal	Yes	No	Yes	Yes
4.2	Installation of waste paper/plastic container	Internal	Yes	Yes	Yes	No
4.3	Usage of reusable packaging system to wrap incoming and outgoing products.	External	Yes	Yes	No	N.A.
5.	**Process optimisation**					
5.1	Extension of life-span of etching bath.	Internal	Yes	No	Yes	No
(5.2)	Approval of chrome-free pre-treatment chemical from Qualicoat.	External	N.A.	N.A.	Yes	Yes
5.3	Elimination of de-smutting process step.	Internal	Yes	No	No	N.A.
5.4	Replace the TGIC-hardener in powder coating.	External	Yes	No	Yes	No
5.5	Expand business by investment in a blasting machine.	External	Yes	Yes	Yes	Yes
6.	**Product design**					
6.1	No identified improvement options for "Product Design".	N.A.	N.A.	N.A.	N.A.	N.A.

Ref. no.	Additional improvement options identified by industrial network approach	Internal or external option?	Identified by network impact matrix?	Identified by brain-storming session?	Selected for feasibility analysis	Estimated feasible for company?
7.	**Transport**					
7.1	No identified improvement options for "Transport".	N.A.	N.A.	N.A.	N.A.	N.A.
8.	**Wastes**					
8.1	Participation in waste exchange programme.	External	No	Yes	Yes	Yes
8.2	Re-winning of chrome and aluminium out of the generated sludges.	Internal	Yes	No	No	No

Table 5.15 Overview of Results of Network Impact Matrix and Brainstorming Session

Table 5.16 can be compiled from the above table. This table evaluates to what extent the network impact matrix and the brainstorming session are able to identify additional (feasible) options which were not identified by the waste minimisation assessment at the powder coating company. Option 5.2 is not incorporated in the following table as it was initially identified by the waste minimisation assessment and does, therefore, not add value to the industrial network assessment.

	Number of improvement options								
	Identified			Selected for feasibility analysis			Estimated feasible		
	Internal option	External option	Total	Internal option	External option	Total	Internal option	External option	Total
Only by network impact matrix	6	2	8	3	2	5	2	0	2
Only by brainstorming session	3	1	4	2	1	3	1	1	2
Identified by both the network impact matrix & brainstorming session	3	2	5	3	1	4	1	1	2
Total	12	5	17	8	4	12	4	2	6

Table 5.16 Analysis of Network Impact Matrix and Brainstorming Session

The network impact matrix initially identified more internal and external options than the brainstorming session. However, an equal number of feasible options were identified by both routes. Therefore, the improvement options identified by the brainstorming are considered to be of a higher quality than the options identified by the network impact matrix.

The aim of the industrial network assessment, conducted at the powder coating company was to identify eco-efficient improvement options in the industrial network of the company. The effectiveness of the network impact matrix and the brainstorming session is determined by the number of feasible external options.

As shown in Table 5.16, the network impact matrix and the brainstorming session only identified two feasible external improvement options in total. The brainstorming session covered both of these feasible external improvement options for the powder coating company. The completed network impact matrix is therefore considered of limited value for the powder coater.

5.9 Conclusions

The industrial network assessment conducted at the powder coating company, identified both internal and external improvement options for the powder coating company.

Eight out of twelve internal options identified by the industrial network assessment, would most probably have been identified in one of the subsequent improvement cycles of the waste minimisation assessment, as waste minimisation is a process of continuous improvement. Four internal improvement options were not identified by the waste minimisation assessment due to the limited scope of the waste minimisation methodology (see Subsection 5.7.4).

The quantity and quality of the internal improvement options are not viable criteria to determine the effectiveness or value of the industrial network approach. The aim of the industrial network assessment was to identify external improvement options that are feasible for the powder coating company.

The industrial network approach identified five external improvement options of which only two options were estimated feasible for the powder coating company. Two external options, not feasible for the powder coating company, were estimated feasible for one or more network partners of the powder coater. However, this is not the aim of the industrial network assessment.

Three external improvement options are not estimated feasible for the powder coating company, because:
- the option is not directly beneficial to the case-study company (option 2.1);
- extensive effort is required to implement the option (option 2.1/option 4.3);
- the option has a negative effect on quality of the product (option 5.4).

Both external improvement options, estimated feasible for the case-study company, were covered by the network brainstorming session. The conducted network impact matrix is therefore regarded of limited value to the powder coating company as it did not identify unique external improvements feasible for the company itself.

Based on the experimental results of the powder coating company, it can be concluded that the conduction of the developed industrial network assessment in addition to a waste minimisation assessment is of limited value.

6 Evaluation of the Industrial Network Approach

6.1 Introduction

This chapter evaluates the industrial network approach based on the experiments conducted with the textile printing company and the powder coater.

The aim of this evaluation is to address the strengths and weaknesses of the developed methodology in order to explain why the methodology did not meet expectations and to make suggestions for further development of the industrial network approach.

The evaluation methodology is described first, and in the sections thereafter each phase within the industrial network assessment is evaluated separately. After discussing each phase, ratings for the complete industrial network assessment are determined and evaluated. At the end of this chapter, conclusions will be presented which will discuss the strengths and weaknesses of the conducted experiments with the two case-study companies.

It should be mentioned that the testing of the industrial network assessment is based on a limited number of case study companies. The reliability of this evaluation can therefore not be guaranteed. However, it provides a good foundation for the evaluation of the developed approach.

6.2 Method of Evaluation

Each phase within the industrial network assessment will be evaluated separately. *These phases concern:*

- Inventory phase
- Assessment phase
- Discussion/selection phase
- Feasibility phase

The four phases are evaluated on the following seven criteria:

1. *Time-investment*, which assesses the experienced time-investments to complete a phase successfully.
2. *Effectiveness* concerns the quality or usefulness of the achieved results.
3. *Efficiency* is determined as the ratio between the time-investment (criteria 1) and the quality of results (criteria 2).
4. *Required skill level* assesses the expertise or knowledge needed to successfully complete a phase within the industrial network assessment.
5. *Participation of company staff / network partners* assesses the quantity (number) and quality (willingness to co-operate) of involved staff members and network partners of the powder coating company during each phase.
6. *Complexity* is defined as the time and effort required for the participating staff member(s) to fully understand the purpose, structure and functioning of each phase.
7. *Systematic approach* examines to what extent the results of each phase were achieved in a structured and systematic manner.

Each evaluation criteria is rated according to one of the following five categories:

- *Significant strength (score 2)* is assigned if an evaluation criteria has a considerable positive impact on the conducted experiments and its results, without having any negative features which decreased the value of the experimental work and/or reduced the quality of the results.

- *Moderate strength (score 1)* is allocated to an evaluation criteria which has an overall positive impact on the conducted experiments and its results, but also has certain negative features which decreased the value of the experimental work and/or reduced the quality of the results.
- *Neutral/indeterminate (score 0)* is assigned if an evaluation criteria has both positive and negative features regarding the experimental work and its results, or if the rating of an evaluation criteria cannot be determined.
- *Moderate weakness (score –1)* means that an evaluation criteria has an overall negative impact on the conducted experiments and its results, but also has a number of positive features which increased the value of the experimental works and/or improved the quality of the results.
- *Significant weakness (score –2)* is allocated to an evaluation criteria which has a considerable negative impact on the conducted experiments and its results, without having any positives features which increased the value of the experiments and/or improved the quality of the results.

6.3 Inventory Phase

This section evaluates the inventory phase of the industrial network assessment conducted at the textile printing compan and the powder coating company.

Figure 6.1 shows the ratings of the evaluation criteria for the inventory phase. If necessary, the evaluation criteria are discussed separately for the textile printing and the powder coating company. Each evaluation criteria will be discussed in the following subsections.

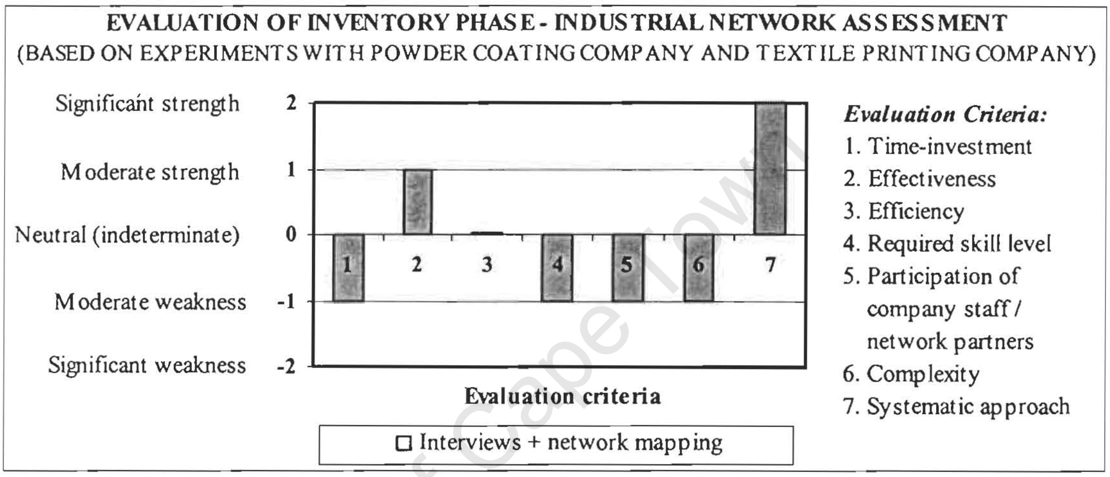


Figure 6.1 Evaluation of Inventory Phase

6.3.1 Time-investment

At the textile printing company, the interviews to gather the network data were held with various staff members as knowledge of, and expertise in, all network sections was not concentrated in the company. Several meetings, with a duration of between half an hour and one hour, were held with each staff member to complete worksheets of one or more network sections.

At the powder coater, the worksheets of all network sections were discussed with the company's managing director, and no other staff members were involved. Two interviews, with durations of about one and a half hours each, were required to gather the relevant information for the network mapping.

According to the information gathered during the interviews, the mapping of the industrial network was done by the facilitator of the industrial network assessment by using a flow-charter computer programme. The facilitator spent approximately three working days on the actual mapping of the networks for each company.

For both companies, the mapped industrial network was discussed with the managing director as the worksheets did not contain all the required network information and certain issues had to be clarified. Several meetings, with durations of half a hour to one hour, were required to explain and discuss the industrial network.

The total invested time for the mapping of the industrial network is perceived as a moderate weakness. Although the staff members were knowledgeable on the structure of functioning of the network around the company, considerable time-investment was required to gather detailed information on the relationships with network partners. It has to be questioned whether this extensive information gathering contributes to the identification of improvement options within the company's network.

6.3.2 Effectiveness

During the interviews to gather the network information, worksheets were used as a guideline for discussion. These worksheets were considered of significant value as they ensure that all the required information is gathered.

The network mapping could largely be done by consulting the completed worksheets, although additional meetings with the managing directors were needed to discuss the mapped industrial network in order to make it more reliable and representative. It is believed that the worksheets cannot contain all the relevant information for the network mapping and that a discussion of the mapped network will remain necessary. On the other hand, the worksheets also include issues which do not directly contribute to the network mapping. The mapped industrial network of the textile printing and the powder coating companies is shown in respectively Appendix G and M.

The contribution of the completed worksheets to the network mapping and the quality of the mapped network itself can be regarded as positive. The mapped industrial network gives a good overview of what is happening around the case-study companies in terms of material, financial and information flows.

The mapped industrial network was of limited use for the companies because the managing directors of both companies were already knowledgeable on the structure and functioning of their companies' networks. The mapped network did not provide any new knowledge to them. Therefore, only the facilitator of the industrial network assessment benefited from the mapped network as he was not yet familiar with the company's network. The effectiveness of the inventory phase is considered a moderate strength.

6.3.3 Efficiency

The worksheets had a positive effect on the efficiency of the data gathering during the company interviews. With the worksheets, it was possible to get concise and valuable feedback from staff members.

In principle, only information regarding the material, financial and information flows between the textile printer/powder coater and its network partners needed to be gathered for the network mapping. It was also found that more than the necessary information was gathered during the interviews due to the structure of the worksheets. For example, the worksheet "Suppliers" also assesses the importance of suppliers for the powder coating company which is not of direct value for the mapping of an industrial network. It is recommended that the worksheets be reviewed on relevance for the network mapping in order to improve the efficiency of the network mapping. The framework of the worksheets can be found in Appendix A.

The efficiency is defined as the ratio between the invested time and the quality of the results. The time-investment for the completion of the inventory phase is estimated as moderate weakness. The quality of the network mapping for both companies was considered as a moderate strength. The efficiency of the inventory phase is therefore rated as indeterminate/neutral.

6.3.4 *Required Skill Level*

The facilitator was responsible for leading the interviews and the mapping of the industrial network of the companies. The company's responsibility was to provide the required network data.

Before conducting the interviews, it was important for the facilitator to familiarise himself with the organisational structure, production processes and products of the textile printing company and the powder coating company. The pre-assessment report for the company, which was written for waste minimisation purposes, proved very useful in this regard.

During the interviews, the facilitator had to be able to absorb and summarise the answers and information given by the staff members in the worksheets. Background knowledge of textile printing / powder coating processes and the textile / metal finishing industry was therefore required.

The interviewees at both companies were open, knowledgeable and willing to discuss the relationship with the company's network partners. This was regarded as a very valuable requirement.

The visualisation of the industrial network with the flow-charter software required advanced computer skills.

It can be concluded that the required skill level to complete the inventory phase of the industrial network assessment is a moderate weakness.

6.3.5 *Participation of Company Staff / Network Partners*

The participation of company staff in the inventory phase of the industrial network assessment consisted of providing the required network information and discussing the mapped industrial network with the facilitator.

At the textile printing company, the interviews to gather the network data were held with various staff members as knowledge and expertise of all network sections was not concentrated in the company. During the introduction meeting with the managing director, it was determined who were the best staff members to discuss each network section with. For example, the worksheet "suppliers" was discussed with the production managers as they were responsible for purchasing the process chemicals and other products related to the production process. The sales representative was interviewed to complete the worksheet "clients". The more confidential issues were discussed with the managing director; viz. the worksheets "shareholders" and "competitors".

In an introduction meeting at the powder coater, it was decided to begin to have the network mapping interviews with the managing director. During these interviews, it could be determined if other staff members or network partners should get involved as well. All worksheets of the network sections and the mapped network of the company could be discussed with the managing director as he was knowledgeable on all network aspects of the company. All the required data was readily available; the managing director had to contact other staff members or network partners only for a few network issues. The mapped network of the powder coating company is, therefore, almost entirely based on the information given by its managing director. Some network issues might have been overlooked or estimated incorrectly. It is always better to have the interviews and discussions with various staff members, or even network partners. This was only done to a limited extent at the powder coating company due to time-constraints within the company.

The interviewees, who provided the network mapping data, should be carefully chosen because the quality of the network mapping depends largely on their input. Before starting the network mapping exercise, it is important to determine who the appropriate staff members are to interview.

The willingness of the participating staff members of both the textile printing and the powder coater to co-operate can be considered as positive, although the direct purpose of the network mapping was initially questioned by the managing director of the powder coating company.

For both the textile printing company and the powder coating company, no network partners were interviewed to gather network data or to discuss the industrial network of the company.

The rating of the evaluation criteria "Participation of company staff / network partners" is based on quantity (number) and quality (willingness to co-operate) of the participated staff members and network partners. Although participating staff members were willing to co-operate, this evaluation criteria is rated as a moderate weakness as more involvement from staff members and network partners would have improved the accuracy of the mapped networks.

6.3.6 Complexity

The evaluation criteria "Complexity" is defined as the required time and effort for the participating staff member(s) to fully understand the purpose, structure and functioning of the network mapping procedure.

The interviews, held to gather the network data, were based on worksheets which contain the relevant points of attention to map the company's network. These interviews are not considered as complex as they were characterised by a "question-answer" style and were fairly straightforward in order to collect the required data as efficiently as possible.

The complexity of the mapped network was considered as significant by the company's managing directors. The mapped networks of both the textile printing and the powder coater are based on the industrial network model, as given in Chapter 1 "Introduction". This model cannot be regarded as complicated. The mapped network is regarded as complex because all material, financial and information linkages, with different magnitudes, between the textile printing / powder coating company and its network partners are visualised in one diagram which is plotted on A1-sized paper. The complexity of the inventory phase is therefore rated as a moderate weakness.

6.3.7 Systematic Approach

The evaluation criteria "Systematic approach" for the inventory phase examines to what extent the network mapping procedure is structured in a systematic manner.

The interviews were structured by the worksheets, which provided a solid framework for the gathering of the required network information. For each network section, a separate worksheet was developed in order to gather the relevant data for the visualisation of the industrial network of the textile printing and powder coating company.

A flow-chart computer programme is used for the visualisation of the company's industrial network. A basic lay-out for the industrial network was set up in the flow-charter software in order to structure the mapped networks. Within these mapped networks, network partners are visualised by black-boxes and material, financial and information flows between the case-study company and its network partners by black, blue and red arrows respectively.

The magnitudes of the material, financial and information linkages, were classified in five different categories, varying from very low to very high. Absolute values per time-period are attached to each category in order to determine systematically the magnitude or weight of the various linkages.

The systematic approach of the inventory phase, viz. the data gathering interviews and the visualisation of the company's industrial network, can be considered as a significant strength. This high systematic approach has a considerable positive effect on the required time-investment and the quality of the results of the inventory phase and the industrial network assessment in general.

6.4 Assessment Phase

The evaluation of the assessment phase of the industrial network assessment is conducted in this section.

Figure 6.2 shows the ratings of the evaluation criteria for the assessment phase. As shown in this figure, the brainstorming session and the network impact matrix are evaluated and rated separately.

The evaluation of the improvement options, identified by the conducted waste minimisation assessment, is part of the assessment phase. However, this economic, environmental and technical evaluation of the waste minimisation options was already done by the facilitator of the waste minimisation assessment and will, therefore, not be discussed in this section.

If necessary, the evaluation criteria will be discussed separately for the textile printing and the powder coater. Each evaluation criteria will be discussed in the following subsections.

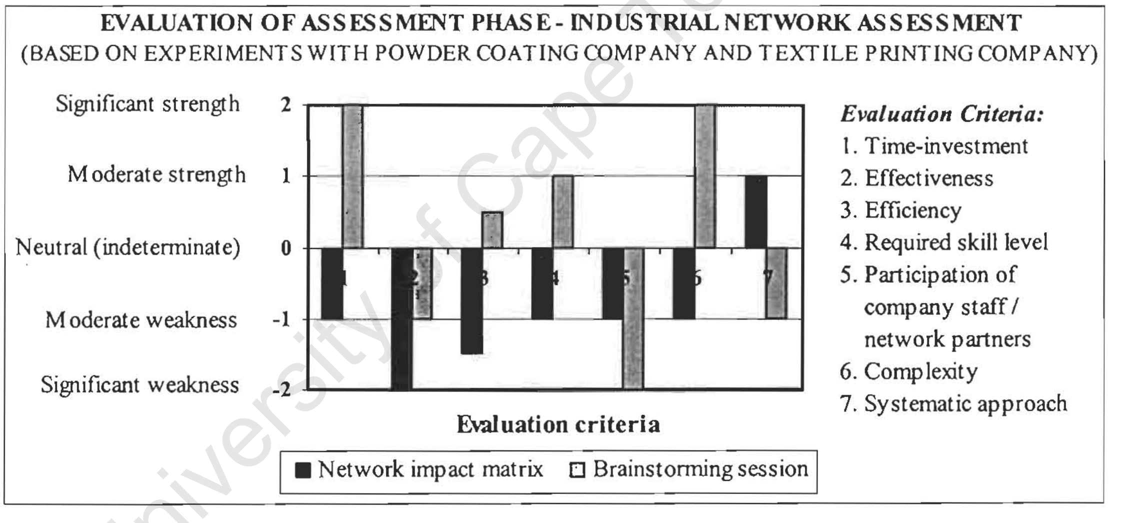


Figure 6.2 Evaluation of Assessment Phase

6.4.1 Time-investment

6.4.1.1 Network Impact Matrix

For both the textile printing and the powder coating companies, the network impact matrix was completed over a time-period of approximately two months. During these two months, considerable effort and time was invested by the facilitator of the industrial network assessment.

Several meetings were held with the staff members of the case-study companies to clarify questions and gather additional network data. The duration of these meetings varied from half an hour to one hour. The facilitator also consulted several LCA-experts and industry specialists to clarify issues which could not be answered by the companies' staff members.

The total time-investment for the completion of the network impact matrix can be regarded as a moderate weakness as considerable effort is required from the facilitator of the industrial network assessment to complete the network impact matrix successfully.

6.4.1.2 *Brainstorming Session*

At the textile printing company, the brainstorming session was done during three meetings. The brainstorming session at the coating company took two meetings. The duration of the discussion meetings was approximately one hour each. For both companies, the brainstorming sessions were held over a time-period of two weeks and were done only with the managing director of each company.

A checklist was used as a guideline during the meetings, which included 50 questions divided into eight categories. On average, two to three minutes were spent per question.

The total time-investment to complete the brainstorming session can be considered as a significant strength. This is largely due to the fact that only the managing director participated in the brainstorming sessions. If the brainstorming sessions had been attended by a larger number of staff members, the total time-investment would have been considerably higher.

6.4.2 ***Effectiveness***

The effectiveness, or quality of the results, of both the network impact matrix and the brainstorming session is determined by the number of external improvement options which are estimated feasible for the case-study companies. Table 6.1 evaluates the effectiveness of the network impact matrix and the brainstorming session, as experienced at the two case-study companies.

	Number of external improvement options								
	Identified			**Selected for feasibility analysis**			**Estimated feasible for the company**		
	Printer of textiles	**Powder coater**	**Total**	**Printer of textiles**	**Powder coater**	**Total**	**Printer of textiles**	**Powder coater**	**Total**
Only by network impact matrix	1	2	3	1	2	3	1	0	1
Only by brainstorming session	3	1	4	3	1	4	1	1	2
Identified by both the network impact matrix & brainstorming session	3	2	5	3	1	4	1	1	2
Total	7	5	12	7	4	11	3	2	5

Table 6.1 Network Impact Matrix versus Brainstorming Session

6.4.2.1 *Network Impact Matrix*

The network impact matrix generated only 1 feasible external improvement option for the textile printing company which was not identified by the brainstorming session. The network impact matrix did not identify any unique options which were found feasible for the powder coating company. For both case-study companies, one feasible external option was identified by both the network impact matrix and the brainstorming session.

Based on these results, the overall estimation of the effectiveness of the network impact matrix is considered to be a significant weakness.

6.4.2.2 *Brainstorming Session*

The network brainstorming session, held with the textile printing company, identified 1 unique external option estimated feasible for the company. The brainstorming session also generated 1 feasible external improvement for the powder coating company which was not identified by the network impact matrix. For the textile printing and powder coating company, 1 feasible external option was generated by both the network impact matrix and the brainstorming session.

Compared to the network impact matrix, the brainstorming session identified more feasible options. However, the number of generated options is limited. The effectiveness of the brainstorming session is therefore rated as a moderate weakness.

6.4.3 *Efficiency*

The efficiency is defined as the ratio between the invested time and the quality of the results.

6.4.3.1 *Network Impact Matrix*

The time-investment to complete a network impact matrix is regarded as being a moderate weakness, while the effectiveness is rated as a significant weakness. The efficiency of the network impact matrix can, therefore, be rated between a significant and a moderate weakness.

6.4.3.2 *Brainstorming Session*

The invested time to conduct the brainstorming session was regarded as a significant strength and the effectiveness was determined as a moderate weakness. The efficiency of the brainstorming session can be estimated between neutral and a moderate strength.

6.4.4 *Required Skill Level*

6.4.4.1 *Network Impact Matrix*

For both the textile printing and the powder coater, the facilitator of the industrial network assessment was responsible for the completion of the network impact matrix. The company's responsibility was to provide the correct data to the facilitator in order to successfully conduct the network impact matrix.

Considerable knowledge of chemical and environmental engineering was required from the facilitator to conduct the network impact matrix. Background knowledge of textile printing / powder coating processes and the textile / metal finishing industry was also required.

The staff of both companies could provide all missing information and was able to answer all the facilitator's questions. They proved to be knowledgeable about the chemistry of the companies' production processes, which was regarded as a valuable requirement.

It can be concluded that the required skill level for the completion of a network impact matrix is a moderate weakness as relatively high qualifications and skills were required from the facilitator of the industrial network assessment to conduct a network impact matrix. However, the facilitator could consult the case-study companies and industry experts when issues needed to be clarified.

6.4.4.2 Brainstorming Session

The facilitator was responsible for leading the brainstorming sessions, which were held with the managing directors of the textile printing and the powder coating company. The managing director indicated which topics in the checklist were worth investigating in more detail.

Management skills were required from the facilitator in order to lead a brainstorming session successfully.

The managing directors identified the potential improvement options according to the checklist which was used during the brainstorming session. The checklist itself only provided starting point for discussion. The interviewees were very open during the discussions and willing to discuss all topics summarised in the brainstorming checklist.

The required skill level for the brainstorming session can considered as a moderate strength; no high qualifications or advanced skills were required from neither the facilitator nor the participant of the brainstorming session to complete the brainstorming successfully. However, the participants of the brainstorming session have to be well familiarised with one or more aspects of the company's activities as the results of the brainstorming session depend largely on their input and judgement.

6.4.5 *Participation of Company Staff / Network Partners*

The rating of the evaluation criteria "Participation of company staff / network partners" is based on quantity (number) and quality (willingness to co-operate) of the participating staff members and network partners.

6.4.5.1 Network Impact Matrix

Limited participation of company staff or network partners was experienced while conducting the network impact matrix for both case-study companies. Most of the information needed to conduct the network impact matrix was already gathered during the inventory phase of the industrial network assessment and, of course, during the waste minimisation assessment at the powder coater. The company staff and network partners "only" provided the missing data to the facilitator in order to successfully complete the network impact matrix.

For the textile printing company, the process engineer was consulted for questions or gathering additional data as he was knowledgeable on all aspects of the production process of the company. At the powder coating company, the managing director was consulted.

Both the process engineer and the managing director were open and willing to provide the missing information and to answer the questions of the facilitator. Only for a few questions was a supplier, a waste treatment organisation or another network partner contacted.

The participation of company staff and network partners during the conduction of the network impact matrix is rated as a moderate weakness due to the low number of participating staff members and network partners. However, the involved company staff showed willingness to co-operate.

6.4.5.2 Brainstorming Session

The brainstorming session was led by the facilitator and done with the managing directors of the textile printing / powder coating company. The managing director indicated which topics in the checklist were worth investigating in more detail.

The contribution of the managing directors can be regarded as important and constructive. However, it is questioned whether the results of the brainstorming session could have been improved if more company members, or even network partners, had participated in the brainstorming session. Due to staff member time-constraints , only the managing directors of both companies participated in the brainstorming session. Although the managing directors had knowledge on all aspects of the company, staff members of different disciplines (purchase, production, maintenance, etc.) could have made a valuable contribution during the brainstorming session.

The quality of the brainstorming session depends on the contribution and involvement of staff members and network partners. The participation of company staff and network partners is therefore rated as a significant weakness as only the managing directors of the two case-study companies were involved in the brainstorming session.

6.4.6 *Complexity*

The evaluation criteria "Complexity" is defined as the required time and effort for the participating staff member(s) to fully understand the purpose, structure and functioning of the network mapping procedure.

6.4.6.1 *Network Impact Matrix*

During an introductory meeting, the purpose and structure of the network impact matrix was explained. Although the framework of a network impact matrix, or a matrix LCA, is considerably less complicated than a full LCA, the facilitator had the impression that the network impact matrix was regarded as significantly complex by the company staff of both case-study companies.

It should be mentioned that the structure of the network impact matrix was made more complex by adding sub-categories to all the network sections in order to identify constraints within the company's network more clearly. For example, the pre-manufacturing section was sub-categorised by the various raw materials and process chemicals used by the case-study company; the section "Product manufacturing by company" was sub-categorised by the company's process steps.

Based on the experiences with the textile printing and powder coater, the complexity of the network impact matrix is considered to be a moderate weakness.

6.4.6.2 *Brainstorming Session*

During the brainstorming session, a checklist is used as a guideline. The checklist consists of two columns; one column with the questions and a column in which the comments of the participants of the brainstorming session can be written down. The questions in the checklist are categorised under eight topics in order to structure the brainstorming session. The framework of the checklist can be regarded as uncomplicated and straightforward.

The complexity of the brainstorming session is regarded as a significant strength as the managing directors of the case-study companies were, at once, familiar with the purpose and structuring of the brainstorming session and only limited explanation by the facilitator was required.

6.4.7 *Systematic Approach*

The evaluation criteria "Systematic approach" for the assessment phase examines to what extent the network impact matrix and brainstorming sessions were structured in a systematic manner.

6.4.7.1 *Network Impact Matrix*

The network impact matrix is, as mentioned in previous sections, based on a matrix LCA. This tool distinguishes five environmental concerns, namely material choice, energy use, solid residues, liquid residues and gaseous residues. For every section of the company's network, a subjective rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment), was given to these concerns in order to identify environmental constraints in the industrial network.

The network impact matrix provides a systematic framework to assess the environmental concerns for each section within the industrial network. However, the rating of the environmental concerns is based on subjective criteria. Therefore, the evaluation criteria "Systematic approach" is considered to be a moderate strength of the network impact matrix.

6.4.7.2 *Brainstorming Session*

A checklist is used as a guideline during the brainstorming session. The questions in the checklist are categorised according to eight topics. The actual identification of potential improvement options is done by the participants of the brainstorming session, so the checklist only provides a starting point for discussion.

Although a checklist was used, the evaluation criteria "Systematic approach" is considered to be a moderate weakness of the brainstorming session as the identification of improvements depended on the experiences and openness of the company staff and not on the systematics of the brainstorming checklist.

6.5 Discussion / Selection Phase

This section evaluates the 3rd phase, the discussion/selection phase, of the industrial network assessment conducted at the powder coating company.

In this phase, the potential improvements identified by the network impact matrix and the brainstorming session are summarised and discussed with the company staff in order to select the options which have the highest potential to be successful.

Figure 6.3 shows the ratings of the evaluation criteria for the discussion/selection phase. If necessary, the evaluation criteria will be discussed separately for the textile printing and the powder coater. Each evaluation criteria will be discussed in the following subsections.

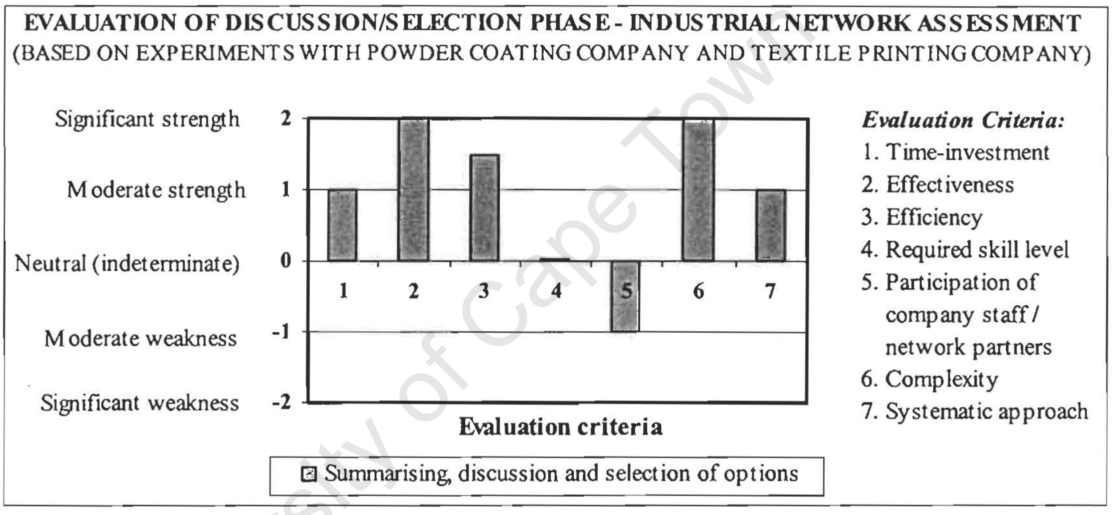


Figure 6.3 Evaluation of Discussion / Selection Phase

6.5.1 Time-investment

The facilitator summarised the identified improvements for the textile printing and the powder coating companies according to the framework developed for this purpose. Approximately two working days were needed per case-study company to complete the summary.

The facilitator discussed the summary of the improvement options identified by the network impact matrix and the brainstorming session with the managing directors of both case-study companies. Based on the information provided in the summary, all identified options were discussed and a selection was made of the improvements with the highest potential to be successful. Approximately two hours were needed per company to discuss the summary.

The time-investment experienced for the discussion/selection phase is regarded as a moderate strength, mainly because limited time was required from the managing directors of the case-study companies to make a proper selection of the identified options.

6.5.2 Effectiveness

It is not viable, time-wise, to conduct a economic, environmental, technical and social feasibility analysis on all identified options. Therefore, a selection should be made of the options with the highest potential to be successful. The end-result of the discussion/selection phase is a list of selected improvement options for which it is worthwhile conducting a feasibility analysis on.

The effectiveness of the discussion/selection phase is defined as the usefulness of summarising, discussing and selecting the identified improvement options and the quality of the selected options.

The facilitator and the company staff of both case-study companies found that the summary was particularly useful as a guideline during the discussion of all identified options. It provided more than enough relevant information to make a reasoned selection of options with the highest potential to be successful. The effectiveness of the discussion/selection phase at the powder coating company is, therefore, regarded to be a significant strength.

6.5.3 *Efficiency*

The efficiency is defined as the ratio between the invested time and the quality of the results. The time-investment of the discussion/selection phase is considered to be a moderate strength, the effectiveness was rated as a significant strength. Therefore, the efficiency of this 3rd phase of the industrial network assessment is regarded as being between a moderate and a significant strength.

6.5.4 *Required Skill Level*

The facilitator was responsible for summarising the findings of the network impact matrix and the brainstorming session. The facilitator had to be able to transfer all these findings to a comprehensive summary, which could be used as a guideline during the discussions. It is strongly recommended that the person who is responsible for conducting the assessment phase, also completes the summary of the results. Misunderstanding of the results of the network impact matrix and brainstorming session could lead to an incorrect and/or incomplete summary of the identified improvement options.

The facilitator discussed the summary of all identified options with the managing directors of the textile printing and the powder coater companies. As mentioned in previous sections, the managing directors were very knowledgeable on all aspects of the company. The managing directors' contribution proved to invaluable during the discussion of the summary.

Options with the highest potential to be successful were selected by the managing directors of both case-study companies, with assistance and advice from the facilitator. This selection was found to be the most critical part of the discussion/selection phase as a feasibility study will be carried out only for the selected options. There will no follow-up action if an option is not selected. Each option should therefore be carefully examined based on the information provided in the summary. It would be regrettable if a feasible option is not selected and therefore not implemented.

Although no significant high qualifications or skills were required to complete the summary of the identified improvement options, the required skill level is considered to be neutral or indeterminate as the assessment and selection of the identified improvement options required considerable experience and insight from the managing director.

6.5.5 Participation of Company Staff / Network Partners

The rating of the evaluation criteria "Participation of company staff / network partners" is based on the quantity (number) and the quality (willingness to co-operate) of the participating staff members and network partners.

Only the managing directors of the textile printing and powder coating companies participated in the discussion/selection phase of the industrial network assessment. No other staff members or network partners were involved during the discussion of the identified improvement options.

It is important that at least one manager with a high hierarchical-position in the organisation is involved in the discussion and selection process in order to establish or maintain management commitment to the feasibility analysis and the possible implementation of the selected improvement options. This was certainly achieved at the both case-study companies.

The willingness of the managing directors to discuss and select the identified options can be regarded as positive as they realised that it was not viable to conduct a feasibility analysis on all identified options.

The participation of company staff and network partners for the discussion/selection phase is rated as a moderate weakness as more involvement from staff members, and even network partners, would benefit the discussion/selection process and also the possible implementation of the options.

6.5.6 Complexity

The evaluation criteria "Complexity" is defined as the required time and effort for the participating staff member(s) to fully understand the purpose, structure and functioning of the discussion/selection phase.

The framework, which is used to summarise the results of the network impact matrix and brainstorming session, can be regarded as uncomplicated. Only the necessary information to make a constructive selection of the most potentially successful options was presented in the summary.

The complexity of this phase was found to be a significant strength for both case-study companies as the managing directors became familiar with the purpose and structure of the discussion/selection phase without any difficulty.

6.5.7 Systematic Approach

The evaluation criteria "Systematic approach" for the discussion/selection phase examines to what extent the identified improvement options were summarised, discussed and selected in a constructive and systematic manner.

The summary of all identified improvement options was structured according to the framework described in Chapter 3 / Section 3.8. For each option, it was identified who will benefit from the implementation, what actions are required to implement the option and which network partners should or could get involved to improve the feasibility of the option. For the powder coater, it was also determined if the option was already identified by the waste minimisation conducted prior to the industrial network assessment.

The systematic approach of the discussion/selection phase is regarded as being a moderate strength as the summary was structured according to a comprehensive framework which streamlined the discussion of the options with the managing directors of the case-study companies to a large extent. However, the selection of the potentially most successful options was still based on the experiences and opinion of the managing directors of both case-study companies.

6.6 Feasibility Phase

The feasibility phase of the industrial network assessment, based on the experiments with the textile printing and the powder coating companies, is evaluated in this section.

The feasibility analysis includes an environmental, economic, technical and social assessment on the selected improvement options.

Figure 6.4 shows the ratings of the evaluation criteria for the feasibility phase. If necessary, the evaluation criteria will be discussed separately for the textile printing and the powder coater. Each evaluation criteria will be discussed in the following subsections.

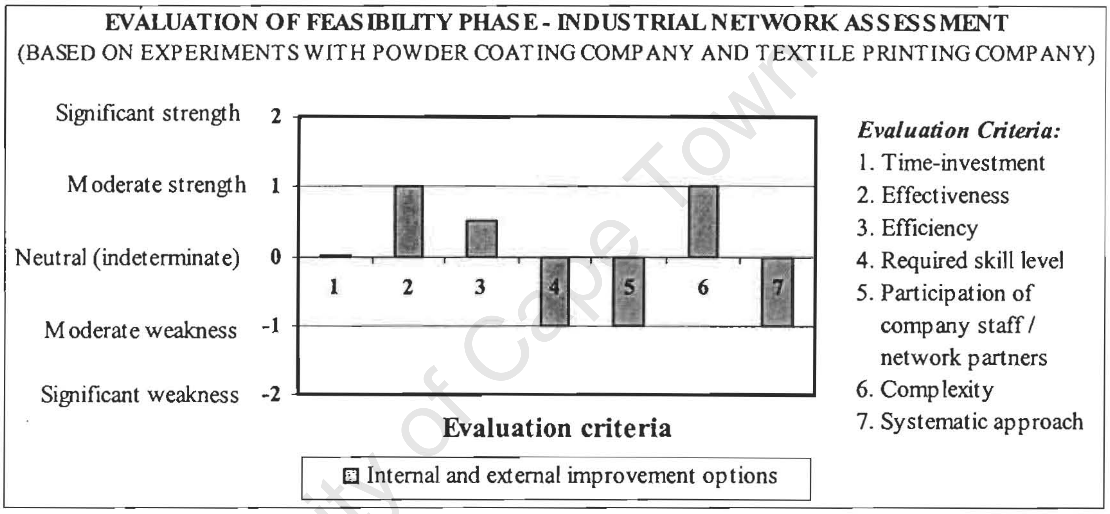


Figure 6.4 Evaluation of Feasibility Phase

6.6.1 Time-investment

A feasibility analysis on the selected improvement options was conducted by the facilitator of the industrial network assessment. A very detailed feasibility analysis was not carried out by the facilitator due to time constraints. Staff members, network partners and industry specialists were consulted to obtain additional data on the options for both the textile printing company and the powder coating company.

The total time-period, in which the feasibility analysis was conducted, was approximately five weeks. During these five weeks, the facilitator spent approximately ten full working days on the feasibility analysis for each case-study company. The required time-investment to complete a rough feasibility analysis on the selected options is regarded as neutral / indeterminate.

6.6.2 Effectiveness

The effectiveness is defined as the quality or usefulness of the conducted feasibility analysis for the implementation of the options.

During the feasibility analysis, all selected options were assessed on environmental, economic, technical and social aspects which could or will occur during implementation.

Although the feasibility studies were not that detailed, it was possible to determine whether or not an option an option was feasible. However, most feasible options would need further investigating and follow-up before being implemented. The effectiveness of the completed feasibility phases for both case-study companies is therefore determined as a moderate strength.

6.6.3 Efficiency

The evaluation criteria "efficiency" of the feasibility phase is defined as the ratio between the required time-investment and the effectiveness of the conducted feasibility studies. The time-investment was regarded as neutral / indeterminate and the effectiveness was rated as a moderate strength. The efficiency of the feasibility phase can therefore be rated between neutral and significant strength.

6.6.4 Required Skill Level

For both the textile printing and the powder coater, the completion of the feasibility analysis was the responsibility of the facilitator. Although the feasibility analysis was not very detailed, the facilitator had to be able to determine or estimate the expected environmental, economic, technical and social implications for the implementation of the selected options.

The facilitator consulted staff members, network partners and industry specialists to obtain missing information for the completion of the feasibility studies. These people have to have knowledge of, or expertise in, one or more criteria of the feasibility analysis for a specific option.

The required skill level for the feasibility phase is rated as a moderate weakness because the feasibility studies concern the estimation of environmental, economic, technical and social impacts of the selected improvement options. To judge these future impacts correctly or as accurately as possible, considerable knowledge or expertise is required from all participants. However, the advantage is that various sources can be consulted for advice.

6.6.5 Participation of Company Staff / Network Partners

The evaluation criteria "Participation of company staff / network partners" concerns the quantity (number) and quality (willingness to co-operate) of the staff members and network partners who contributed to the completion of the feasibility phase.

For the textile printing company, the process engineer assisted the facilitator with providing company-specific data required by the feasibility study. At the powder coating company, this role was performed by the managing director.

The feasibility study for both case-study companies required expertise or advice from various network partners. For example, the suppliers of the textile company were contacted to find out whether their chemicals could be supplied in reusable packaging. The clients of this case-study were also contacted to discuss the feasibility of eco-labelled textiles in South Africa.

The willingness of the company staff and the contacted network partners can be described as positive. Although network partners of the case-study companies were involved in the feasibility phase, it is questionable whether a more intensive involvement of network partners would have led to a more accurate feasibility study. The participation of company staff / network partners is therefore rated as a moderate weakness.

6.6.6 *Complexity*

Complexity is defined as the required time and effort for the participating staff member(s) to fully understand the purpose, structure and functioning of the feasibility phase.

The framework which is used to summarise the results of the feasibility study can be regarded as uncomplicated.

The environmental feasibility assessment of options is based on the seven key-dimensions of eco-efficiency. Each key-dimension can be rated according to three categories which indicate whether the option will have a significant positive, negative or negligible impact on the key-dimension. This assessment method also cannot be regarded as complicated.

The economic, technical and social assessment is not structured in the framework for the feasibility analysis. It is believed that assessment of these three criteria should be structured according to characteristics of the selected options.

Although the feasibility study is conducted according to a framework which required some explanation by the facilitator of the industrial network assessment, the complexity of the feasibility phase is rated as a moderate strength. The followed methodology and applied framework was easy to understand by the managing directors of both case-study companies.

6.6.7 *Systematic Approach*

For the feasibility phase, the evaluation criteria "Systematic approach" examines to what extent the feasibility analysis is conducted in a constructive and systematic matter.

The summary of the feasibility analysis is structured according to a framework which is described in Chapter 3 / Section 3.10. Although the framework structures the feasibility analysis to some extent, the facilitator still had to decide how the economic, technical and social impacts of an option were assessed. The environmental impacts are assessed in a more systematic manner.

The evaluation criteria "Systematic approach" is rated as a moderate weakness as the overall framework for the feasibility study is given, but the completion of the framework still required structuring and expertise from the facilitator of the industrial network assessment at both case-study companies.

6.7 Conclusions

This chapter evaluated the developed industrial network approach based on the conducted experiments with the two case-study companies. Seven criteria were used to address the strengths and weaknesses of the developed methodology.

Figure 6.5 gives a summary of the individual ratings for each phase of the industrial network assessment; these ratings were discussed in previous sections.

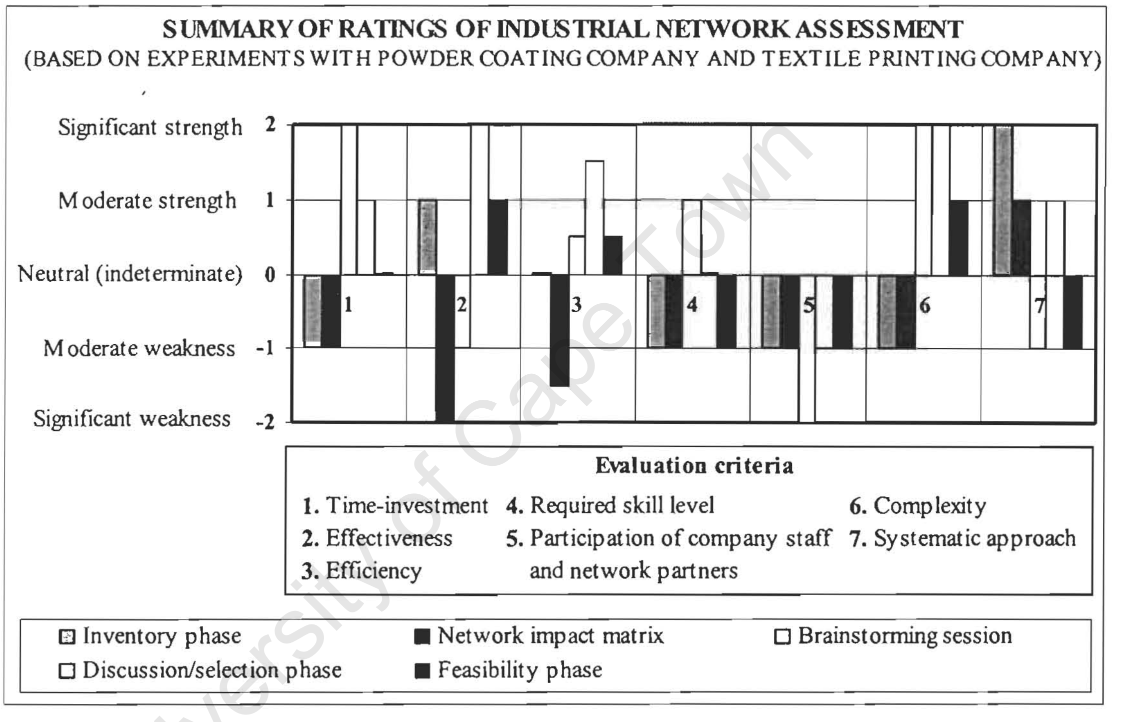


Figure 6.5 Summary of Ratings of Industrial Network Assessment

Suggestions to improve the performance of the developed industrial network approach, by eliminating the identified weaknesses, are discussed in Chapter 7 "Discussion and Conclusions".

7 Discussion and Conclusions

7.1 Introduction

Based on Chapter 2, the literature review, a methodology was developed for the identification of eco-efficient improvement in the industrial networks of SMEs (Chapter 3). As discussed in Chapter 4 and 5, the industrial network approach as developed and described in this thesis is perceived to be of limited value for SMEs. The strengths and weaknesses of the developed industrial network approach were evaluated in Chapter 6.

This chapter summarises the results of this Masters project and offers a conclusion regarding the findings. In Section 7.2, suggestions to improve the performance of the developed methodology are outlined. Three scenarios to conduct an industrial network assessment in combination with a waste minimisation (WM) assessment are discussed in Section 7.3. The incorporation of the industrial network assessment in the existing WM-methodology is the suggested and the preferred scenario and is discussed separately in Section 7.4. The final conclusions regarding this research project are outlined in Section 7.5.

7.2 Suggestions to Improve the Performance of the Industrial Network Assessment

In order to further develop the industrial network approach, possible ways to eliminate the identified weaknesses of the developed methodology have to be addressed. After giving an overall rating for each phase of the industrial network assessment in Subsection 7.2.1; suggestions are given to improve the performance of each phase of the developed methodology.

7.2.1 Overall Rating of the Phases of the Industrial Network Approach

Figure 7.1 gives an identification of the overall strength or weakness of each phase within the developed industrial network assessment.

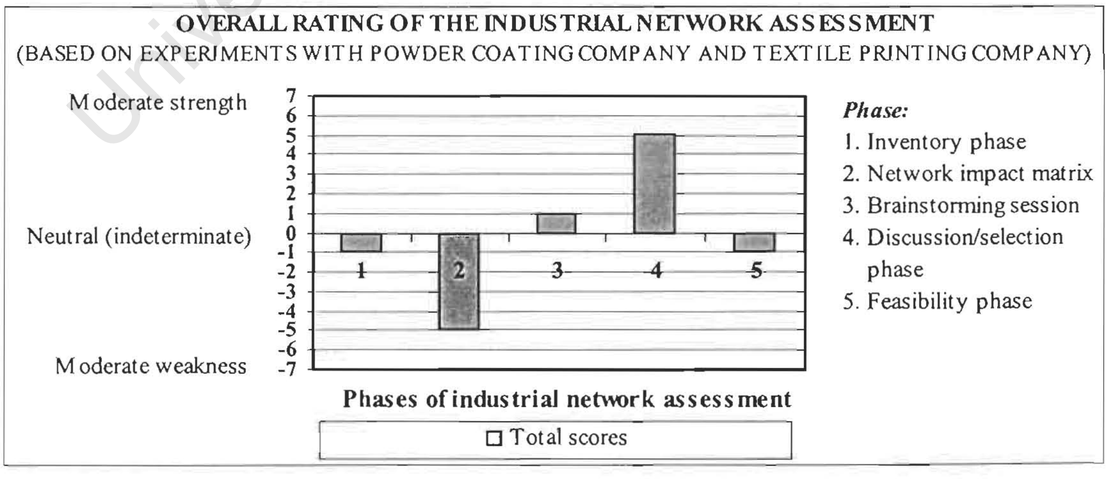


Figure 7.1 Overall Rating of Phases of Industrial Network Assessment

The inventory phase is considered to be an essential part of the industrial network assessment which has potential for further improvement.

As shown in Figure 7.1, the performance of the network impact matrix is regarded as poor. A network brainstorming session appears to be a more appropriate tool to identify improvement opportunities within the industrial network of an SME.

The discussion/selection phase proved to be effective and valuable and is therefore regarded as a strong element within the industrial network assessment.

The feasibility phase is an essential part of the developed industrial network assessment, but its framework needs to be optimised in order to guide the facilitator better through the feasibility phase.

It is stipulated that the overall performance of the industrial network assessment can be improved if the suggested measures, as discussed in the following subsections, are incorporated in the developed industrial network approach.

7.2.2 ***Improvement of the Inventory Phase***

The experienced weaknesses of the inventory phase concern the time-investment, required skill level, participation of company staff and network partners and the complexity of the network mapping.

The time-investment, required skill level and complexity of the inventory phase are criteria which are closely linked together. It is believed that the rating of these three criteria could be improved by simplifying the network mapping worksheets and the way the industrial network is mapped.

The network mapping worksheets contain more questions or issues than necessary. For the network mapping, in principle, only that information which is directly related to the material, financial and information flows between the case-study company and its network partners, needs to be gathered. The modification or simplification of the worksheets would reduce the time-investment and complexity of the inventory phase significantly. Appendix Q gives an overview of which issues in the worksheets could possibly be eliminated without reducing the effectiveness of the inventory phase.

The actual mapping of the company's industrial network was done with flow-charter software; the network was then plotted on A1-paper. The aim of the plotted network is to obtain a holistic view of what is happening "around" the company. The current method surely achieves this; however, the mapped networks were regarded as complex by the company staff involved in the case-studies.

The complexity of the mapped network could be reduced by the exclusion of 'second tier' network partners (eg. client of a client or the supplier's supplier) of the case-study company in the plotted network. Additionally, the rating of the flow intensities in 5 categories ranging from low to very high could be excluded as well. However, it has to be questioned to what extent these modifications will affect the effectiveness of the inventory phase.

It is believed that the modification and simplification of the network mapping worksheets and the plotted network will have a positive effect on the skill level required to complete the inventory phase successfully.

7.2.3 *Improvement of the Assessment Phase*

7.2.3.1 *Network Impact Matrix*

The experienced weaknesses of the network impact matrix are: the time-invested, effectiveness, efficiency, required skill level, participation of company staff and network partners and the complexity. Of these criteria, the main criteria which determine the success or feasibility of the network impact matrix are the effectiveness and efficiency.

While filling in the network impact matrix, the involvement of company staff and network partners was limited to answering questions raised by the facilitator of the industrial network assessment. In other words, the two case-study companies had a passive assisting role. Owing to time-constraints and limited awareness of environmental improvement practices, it is expected that SMEs would find it difficult to conduct the network impact matrix themselves. However, greater involvement and commitment from company staff and network partners should be obtained in order to make the network impact matrix a more effective tool.

Based on the experiments with the textile printing and the powder coating company, it is unlikely that the required time-investment, required skill level and complexity of the network impact matrix can be reduced. The network impact matrix is based on a matrix LCA which is already an abridged version of a full LCA. The network impact matrix was not found to be an effective technique for the identification of eco-efficient improvements in the industrial network of an SME, as it is not feasible for the SME to carried it out.

7.2.3.2 *Brainstorming Session*

The network brainstorming sessions, held with the two case-study companies, were characterised by two weaknesses; the limited participation of company staff and network partners and the lack of a systematic approach.

Having completed the experiments, it is believed that the strength of the brainstorming session largely depends on the quality and quantity of involvement of company staff and network partners. The brainstorming sessions at the two case-study companies, were held with only the company's managing director.

As the managing directors already had a broad understanding of the functioning of the company's industrial network, the mapped network was of limited value during the brainstorming session. However, if more company staff and network partners would participate in the brainstorming session, the mapped network will become more valuable. The mapped network can then be used to explain the characteristics and functioning of the company's network as not all participants of the brainstorming sessions are familiar with all these external aspects of the company. A clear understanding of the company's network will have a positive effect on the individual contribution of each participant. It is believed that, in this way, the brainstorming session will become a more effective tool. Additionally, incorporating the mapped network in the brainstorming session, would be an improvement on the non-systematic approach of the brainstorming session.

The experiments with the two case-study companies showed that the checklist, which is used during the brainstorming session as a guideline, generates both internal and external improvement options. These internal improvement options are mostly typical waste minimisation options. It is not the aim of the industrial network assessment to identify internal improvement options. Therefore, reviewing and updating the brainstorming checklist should be considered in order to make this checklist more suitable for its purpose.

7.2.3.3 *Sequence Network Impact Matrix and Brainstorming Session*

The experiments revealed that there is an overlap of improvement options identified by the network impact matrix and the brainstorming session. Both the network impact matrix and the brainstorming session also identify improvement options which were not identified by the other tool.

Based on the experimental work, it can be concluded that the sequence of undertaking the network impact matrix and the brainstorming session does not influence the quality or quantity of the identified improvement options.

However, it is important to achieve "quick" results in order to motivate company staff members and to maintain management commitment during the industrial network assessment or any other environmental improvement practice. From this viewpoint, it is preferable to conduct the brainstorming session first. The staff members can get familiar with the principles of the industrial network assessment. It is also a relatively simple way to identify improvement options in which the staff members can play an active role.

7.2.4 *Improvement of the Discussion/selection Phase*

Only one weakness was experienced during the discussion/selection phase, namely the limited participation of company staff and network partners.

It is believed that network partners, from whom co-operation for successful implementation of the improvement options is required, should get more involved in the discussion and selection process. By doing this, the effectiveness of this phase is increased as network partners can give their opinion on the potential feasibility of the identified improvement options.

7.2.5 *Improvement of the Feasibility Phase*

The weaknesses of the feasibility phase were found to be the required skill level, the limited participation of company staff and network partners, and the lack of a systematic approach.

It will be difficult to reduce the required skill level for successful completion of the feasibility phase. An estimation has to be made of the environmental, economic, technical and social impacts which will occur during implementation of an option. A relative high level of engineering and management skills is required for these assessments.

Network partners should be more involved in order to make the feasibility study more accurate.

The framework in which the feasibility study is carried out, can be structured in a more systematic manner for a better guide for the facilitator of the industrial network assessment through the feasibility process. For each of the four aspects of the feasibility study, a checklist could be made, which would speed-up the process and would ensure that all relevant issues are addressed.

7.2.6 *Summary of the Suggested Improvements of the Developed Industrial Network Approach*

Table 7.1 gives an overview of the suggested improvements of the developed methodology as discussed in previous subsections.

Phase	**Suggested Improvements**
Inventory phase	modify worksheets to do the network mapping
	simplify structure of the mapped network
	more involvement of company staff / network partners
Assessment phase – network impact matrix	more involvement of company staff / network partners
Assessment phase – brainstorming session	discuss mapped network of company as introduction to brainstorming session
	improvement of brainstorming checklist
	more involvement of company staff / network partners
Discussion / selection phase	more involvement of company staff / network partners
Feasibility phase	optimise structure of framework for feasibility study
	more involvement of company staff / network partners

Table 7.1 Summary of the Suggested Improvements of the Developed Industrial Network Approach

7.3 Industrial Network Assessment versus Waste Minimisation Assessment

A waste minimisation assessment is proposed to be the most appropriate existing methodology to improve the environmental performance of companies [USEPA, 1988]. However, the WM-methodology has limitations which reduces its potential to contribute to the required improvement of the environmental performance of SMEs in the South African manufacturing sector. These limitations include the system's boundaries and the scope and main focus of the waste minimisation assessment. Each limitation was discussed in the literature review.

The developed industrial network approach aimed to overcome the limitations of the WM-methodology. It needs to be discussed how the strengths of the developed methodology can be applied in practice as efficiently and effectively as possible.

The following three scenarios are possible options for conducting the developed industrial network assessment:
- *Scenario 1:* industrial network assessment instead of a waste minimisation assessment
- *Scenario 2:* industrial network assessment in addition to a waste minimisation assessment
- *Scenario 3:* incorporate the industrial network approach in the WM-methodology

The feasibility of each scenario will be discussed in the **following subsections.**

7.3.1 Scenario 1: Industrial Network Assessment Instead of a Waste Minimisation Assessment

This scenario corresponds with the experiments conducted with the textile printing company, as discussed in Chapter 4.

The value of an industrial network assessment instead of a waste minimisation assessment is determined by the total number of identified improvement options feasible for the company.

The experiments with the textile company revealed that the industrial network approach was able to identify both internal and external improvement options. Internal options are mostly typical waste minimisation options and external options concern improvements in the industrial network of the SME. However, the total number of feasible internal and external improvements identified by the industrial network assessment is regarded as low.

The opinion of the author of this thesis is that a completed waste minimisation assessment would have identified more feasible options since the WM-methodology is a proven tool to improve the environmental performance of a company. It is therefore questionable if it is worthwhile for an SME to invest a considerate amount of time and effort to conduct the developed industrial network approach instead of a waste minimisation assessment.

The conclusion is that this scenario is not the preferred one to apply.

7.3.2 Scenario 2: Industrial Network Assessment in Addition to a Waste Minimisation Assessment

The experiments conducted with the powder coating company, as outlined in Chapter 5, correspond with scenario 2.

The value of an industrial network assessment in addition to a waste minimisation assessment is determined by the number of identified external improvement options feasible for the case-study company. The internal improvements, identified by the industrial network assessment, do not add value to the developed methodology as most internal options would have been identified by the waste minimisation assessment conducted prior to the industrial network assessment.

The experimental results of the powder coating company showed that the industrial network approach was only able to identify 2 external options feasible for the case-study company. It is therefore not regarded as efficient or effective for an SME to conduct the full industrial network assessment in addition to a waste minimisation assessment. As waste minimisation is a process of continuous improvement (see Chapter 2 / Subsection 2.4.1 "Description of the WM-methodology"), it is perceived to be more effective for the company to select new focus areas for a detailed assessment of its wastes.

It is therefore also not considered feasible to apply scenario 2 in practice.

7.3.3 Scenario 3: Incorporate Industrial Network Approach in the WM-methodology

Although the developed industrial network approach is not an appropriate tool for South African SMEs to use instead of or in addition to a waste minimisation assessment, the developed approach has elements of value which can be used to optimise the existing WM-methodology. In other words, the strengths of the industrial network approach, as outlined in this thesis, should be incorporated within the WM-methodology.

Scenario 3 is the suggested scenario to be applied in practice and will therefore be discussed in detail in the following section of this chapter.

7.4 Incorporation of the Industrial Network Assessment in the Existing WM-methodology

As concluded in previous section, the incorporation of the industrial network assessment in the existing WM-methodology is the most preferred and recommended scenario for utilising the strengths of the developed methodology.

In this section, a comparison is made of the WM-procedure and the developed industrial network approach in order to propose a modification of the existing WM-methodology.

7.4.1 Comparison of the Waste Minimisation and the Industrial Network Procedure

Table 7.2 compares the procedure for a waste minimisation assessment with the developed industrial network approach. By doing this, insight is gained into the similarities and differences between the waste minimisation and industrial network procedure. This is necessary for the process of incorporating the industrial network approach within the existing WM-methodology.

Waste minimisation assessment	**Industrial network assessment**
Planning and organisation	
- get management commitment - define scope and boundaries of project - set up project team and define responsibilities - set up goals (quantitative and qualitative) and time-planning - identify sources of data and contact persons	Not included in the developed methodology, but was done during experiments.
Pre-assessment phase (inventory phase)	
Rough in-company data: - identify, characterise, and track the facilities of waste streams - draw up process flow charts - determine mass and energy flows - start making rough mass and energy balances - identify the main environmental costs - select main focus areas	*Rough in- and external company data:* - complete worksheets for network mapping (shareholders, suppliers, clients, competitors, utility providing companies, waste treatment/recycling companies, support organisations, governmental and community organisations, maintenance companies) - map industrial network of the company
Assessment phase	
Detailed in-company data (for focus areas): - compile background information on processes, waste types and sources, technologies, WM-practices and environmental impacts - gather additional data - close mass and energy balances - generate options (brainstorming session, literature, WM-checklists, industry experts) - screen and select options for further study	*Detailed in- and external company data:* - complete network impact matrix - generate options (network brainstorming session and evaluation of completed network impact matrix)
Feasibility analysis	
Internal improvement options: - technical evaluation - economical evaluation - environmental evaluation	*In- and external improvement options:* - technical evaluation - economic evaluation - environmental evaluation - social evaluation
Implementation	
Internal improvement options: - get commitment from company management - set up project team - allocate tasks and responsibilities - determine costs - determine time-planning - implementation - evaluate performance	*In- and external improvement options:* - get commitment from company management and involved network partners - set up project team (in- and external members) - allocate tasks and responsibilities - determine costs (and profit sharing between network partners) - determine time-planning - implementation - evaluate performance

Table 7.2 Industrial Network Assessment versus WM-assessment Procedure

7.4.2 Proposed Modification of the Existing WM-procedure

The proposed modification of the existing WM-procedure is shown in Table 7.3. Each modification is marked in bold and numbered. Each modification is discussed in the following subsections.

Phase 1: Planning and organisation
- get commitment from company management **and network partners, or at least inform network partners about project (1)** - define scope and boundaries of the project - set up a project team, consisting of company employees and **network partners (2),** and define responsibilities - set up goals (quantitative or qualitative) and time-planning - identify sources of data and contact persons
Phase 2: Pre-assessment
- identify, characterise, and track the facilities of waste streams - draw up process flow charts - determine mass and energy flows - start making rough mass and energy balances - **identify, characterise network partners and its relationships with the company (3)** - **map industrial network of company (4)** - identify the main environmental costs - select main focus areas
Phase 3: Assessment
- compile background information on processes, waste types and sources, technologies, wm-practices and environmental impacts - gather additional data - close mass and energy balances - generate options (WM-checklists, **industrial network checklist (5),** literature, industry experts) - screen and select options for further study
Phase 4: Feasibility
- technical evaluation - economical evaluation - environmental evaluation - **social evaluation (6)**
Phase 5: Implementation
- get commitment from company management and **network partners (7)** - set up project team, consisting of company employees and **network partners (8),** for implementation of option - allocate tasks and responsibilities - determine costs and **profit sharing with network partners (9)** - determine time-planning - implementation - evaluate performance

Table 7.3 Proposed Modification of the Existing WM-methodology

By modifying the existing WM-methodology with the proposed suggestions, the scope of the WM-assessment is extended. Besides the identification of internal improvement options, the modified WM-methodology also aims to identify improvements in the industrial network in which the company operates naturally (external improvements). It is therefore important to involve network partners of the company during the entire waste minimisation exercise.

7.4.2.1 Modification of Phase 1: Planning and Organisation

In the planning and organisation phase, commitment from the company management for the WM-project has to be obtained. It is suggested that network partners also get involved in this phase as their participation or input might be required in one of the following phases of the project. If it is not practically feasible to get full or official commitment from the network partners. They should however, at least be aware that the company is undertaking a WM-project so that they can be asked to co-operate with the company or provide input when the project progresses **(modification no. 1)**.

The ideal situation would be that network partners join the project team so that they experience the complete WM-process. In this way, network partners are better able to assist the company in identifying eco-efficient improvements for the company and for themselves **(modification no. 2)**.

7.4.2.2 Modification of Phase 2: Pre-Assessment

The aim of the pre-assessment phase of the existing WM-methodology is to get an initial overview of the company's operations, waste streams and emissions to establish focus areas for the assessment phase.

Besides internal improvements, the modified WM-methodology also aims to identify improvements in the industrial network of the company. Without insight into the structure and working of the industrial network of a company, it is difficult to identify these external improvements. Identifying improvement always starts with analysing the matter of concern, in this case the industrial network of a company.

Besides the identification and characterisation of the internal streams of the company, the network partners and their relationship (in terms of material, financial and information flows) with the company also need to be classified. This classification concerns the completion of the worksheets for the network mapping and the mapping of the industrial network itself **(modification no. 3 and 4)**.

7.4.2.3 Modification of Phase 3: Assessment

During the assessment phase of the modified WM-procedure, internal and external improvement options are generated.

Internal improvements, mostly typical WM-options, are generated through discussions with the company staff and industry experts, and also through consultation of available literature and checklists written for waste minimisation purposes.

As shown in Figure 7.1, a brainstorming session is a more appropriate tool to identify external improvements than the network impact matrix. An industrial network checklist can be used during a brainstorming session with company staff and network partners to generate improvements in the industrial network of the company. The mapped industrial network of the company can then be used to introduce and educate the participants of the brainstorming session on the structure and functioning of the company's industrial network. However, the checklist applied during the brainstorming sessions with the case-study companies needs to be improved in order to make the checklist more effective. It is suggested that the industrial network checklist should be based on the list of areas and core drivers for networking initiatives as developed by Rosenthal [1999] and described in Chapter 2 / Subsection 2.5.4 "Drivers and Barriers for Networking of Businesses" of this thesis (modification no. 5).

7.4.2.4 *Modification of Phase 4: Feasibility*

The structure of the technical, economical and environmental feasibility analysis on external improvement options corresponds with the feasibility analysis on internal improvement options. The difference is that the social aspects of implementing external options should also to be taken into account as involvement and co-operation is required from one or more of the company's network partners. Therefore, a social feasibility study is required for the identified external options **(modification no. 6)**.

A social feasibility study assesses the anticipated barriers and opportunities related to the willingness and motivation of the SME and its network partners to co-operate with each other in order to successfully implement an external option.

During a social feasibility analysis, answers have to be given to questions such as:

- Which network partners can or have to co-operate and to what extent?
- What benefits are gained by the involved network partners?
- What will the allocation of tasks, costs and profits be amongst the network partners?

7.4.2.5 *Modification of Phase 5: Implementation*

In order to implement an improvement in the industrial network of the company successfully, commitment is required not only from the company management, but also from network partners. Without their commitment, the implementation of the option is doomed to fail **(modification no. 7)**.

If a feasible external option requires the formulation of a project team, network partners should join the team as well. In this way, an opportunity in the industrial network is addressed by all parties involved . This will have a positive influence on the successful implementation of the option **(modification no. 8)**.

It is important that all involved parties benefit in some way from the implementation of the external option because only then is there an incentive for all parties to co-operate and invest time and money. The financial benefits gained should therefore be shared between the involved network partners **(modification no. 9)**.

7.5 Final Conclusions

The developed industrial network approach does not eliminate the need for a facilitator to assist an SME in improving its environmental practices and therefore, does not improve the limited potential for South African SMEs in the manufacturing sector to improve their environmental performance on their own. As for a waste minimisation assessment, an industrial network assessment can not be carried out without an experienced facilitator.

At the beginning of this Masters research project, the hypothesis was formulated as "feasible eco-efficient improvement opportunities can be found within the industrial network of an SME which would not have been identified by a waste minimisation assessment". The industrial network in which an SME operates naturally offers opportunities for the SME to improve its environmental performance. It can therefore be concluded that this formulated hypothesis is true. However, the developed methodology, as proposed in this thesis, is not an appropriate tool for SMEs to conduct instead of or in addition to a waste minimisation assessment. It is recommended that the strengths of the developed and described industrial network approach be incorporated within the existing WM-methodology.

The existing WM-methodology tends to address environmental improvements only within the company's physical boundaries. By applying the suggested modifications to the WM-methodology, improvements in a company's industrial network can be identified as well; these improvements occur outside the company's physical boundaries.

The developed industrial network approach and the conclusions regarding its practical application are based on experiments in only two case-study companies, namely a textile printing and a powder coating company. Additional experiments are necessary to validate the recommended modifications of the WM-methodology.

The two case-study companies were both South African SMEs. It will be interesting to research the application of the developed industrial approach on large companies, and on companies in a country with a higher standard of environmental practice than South Africa.

During the experiments, it was found that the mapped industrial network of the company was useful for other purposes than the industrial network assessment. The mapped network gives a complete holistic overview of what is happening "around" the company in terms of material, financial and information flows. The mapped network can therefore be used to educate newly appointed staff members or other interested parties on the business activities of the company. An environmental management system could also benefit from the illustration of an industrial network as a mapped network can assist a company in educating its employees on environmental issues and assessing the environmental performance of its network partners.

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GENERAL INFORMATION

Company:	
Address:	
Postal address:	
Tel.number:	
Fax number:	

BLACK-BOX:	CONTACT PERSON:	FUNCTION:	REMARKS:
shareholders			
suppliers			
clients			
competitors			
waste treatment companies			
utility providing organisations			
support organisations			
local government & community organisations			
maintenance			

FLOW CATEGORIES

Purpose of network mapping:

1) to get an overview of what is happening "around" the company in terms of material, financial and information flows
2) to test the method to find eco-efficient improvement opportunities in a SME network
3) to supply data for the development of an interactive environmental/economic model for the SME sector (textile and metal finishing industry)

If exact data is not easily available than the following categories can be used:

flow intensity	material flow [kg/liters/Kwh/products per year]	financial flow [Rands per year]	information flow [personal contact]
very high	> 100,000	> 1,000,000	daily
high	10,000 to 100,000	100,000 to 1,000,000	weekly
medium	1,000 to 10,000	10,000 to 100,000	monthly
low	0 to 1,000	0 to 10,000	yearly

1. SHAREHOLDERS

NAME	MATERIAL FLOW * direction * intensity	FINANCIAL FLOW * direction * intensity	INFORMATION FLOW * direction * intensity	REMARKS (problems & possibilities in the past, present, future)

2. MAJOR SUPPLIERS

NAME	AREA * local * nationa * internat	ACTIVITY * producer * trading * assembl.	PRODUCTS SUPPLIED	AID / POP *	MATERIAL FLOW * direction * intensity	FINANCIAL FLOW * direction * intensity	INFORMATIO FLOW * direction * intensity	RATE OF IMPORTANC OF SUPPLIER * high * medium * low	TRANSPORT (means, who, when, how much)	REMARKS (problems & opportunities in the past, present, future)
Process Chemicals:										
Fuel / oil / greases / gas:										
Paints / solvents										
Packaging:										
Raw materials:										
Product components:										
Tools / machinery:										
Others:										

* AID = Aiding material (not part of product) / POP = Part of Product-material

3. MAJOR CLIENTS

NAME	MARKET * local * national * internat.	PRODUCT PURCHASED	SECOND TIER CLIENTS	MATERIAL FLOW * direction * intensity	FINANCIAL FLOW * direction * intensity	INFORMATION FLOW * direction * intensity	% of turn-over generated by client	TRANSPORT (means, when, who, how much)	REMARKS (problems & opportunities in the past, present, future)

General remarks

4. MAJOR COMPETITORS

NAME	AREA * local * national * internat.	PRODUCTS MANUFACTURED	COMPETITION REGION * local * national * international	COMPETITION TO COMPANY * high * medium * low	AREA OF STRENGTH/ WEAKNESS COMPETITOR	INFORMATION EXCHANGES	INFLUENCE COMPETITOR ON WHO?	REMARKS (problems & opportunities in the past, present, future)

5. UTILITY PROVIDING ORGANISATIONS

NAME	MATERIAL FLOW * direction * intensity	FINANCIAL FLOW * direction * intensity	INFORMATION FLOW * direction * intensity	IMPLEMENTED SAVINGS TECHNIQUES	REMARKS (problems & opportunities in the past, present, future)

6. WASTE TREATMENT AND RECYCLING ORGANISATIONS

1) HAZARDOUS WASTE STREAMS

WASTE TREATMENT ORGANISATION * name * contactperson * telephone number	HAZARDOUS WASTE STREAM	MATERIAL FLOW * direction * intensity	FINANCIAL FLOW * direction * intensity	INFORMATION FLOW * direction * intensity	WASTE TREATMENT PROCESS BY WASTE TREATMENT COMPANY	REMARKS (problems & opportunities in the past, present, future)

2) NON HAZARDOUS WASTE STREAMS

WASTE TREATMENT ORGANISATION * name * contactperson * telephone number	NON-HAZARDOUS WASTE STREAM	MATERIAL FLOW * direction * intensity	FINANCIAL FLOW * direction * intensity	INFORMATION FLOW * direction * intensity	WASTE TREATMENT PROCESS BY WASTE TREATMENT COMPANY	REMARKS (problems & opportunities in the past, present, future)

7. SUPPORT ORGANISATIONS

NAME	PURPOSE OF ASSOCIATION	MATERIAL FLOW * direction * intensity	FINANCIAL FLOW * direction * intensity	INFORMATION EXCHANGES	REMARKS (problems & opportunities in the past, present, future)

Think of:

* Research Institutions
* Knowledge Providing Organisations
* Employer / Industry Organisations
* Employee Organisations /Trade Unions

8. LOCAL GOVERNMENT & COMMUNITY ORGANISATIONS

NAME	PURPOSE OF ASSOCIATION	MATERIAL FLOW * direction * intensity	FINANCIAL FLOW * direction * intensity	INFORMATION FLOW * direction * intensity	REMARKS (problems & opportunities in the past, present, future)

Think of:
* environmental legislation
* sponsoring
* non-governmental organisations (NGO's)

9. MAINTENANCE

NAME	KIND OF MAINTENANCE	MATERIAL FLOW * direction * intensity	FINANCIAL FLOW * direction * intensity	INFORMATION FLOW * direction * intensity	REMARKS (problems & opportunities in the past, present, future)

Ref.no.	NETWORK BRAINSTORMING SESSION – COMPANY CHECKLIST	
1.	**Energy**	**Comments**
1.1	Can waste heat be utilised, exchanged between processes, exchanged between companies?	
1.2	Can energy costs be directly allocated to budgets / process steps to encourage better control?	
1.3	Is there scope for better energy housekeeping? For example: - Can processes or buildings be insulated more effectively? - Can more energy-efficient lighting be installed? - Are buildings maximising use of passive heating and cooling?	
1.4	Can raw materials be produced or dried with less or renewable energy?	
1.5	Can processes be integrated to create energy savings?	
1.6	Is the drying process managed optimally? Can products be manufactured with less energy? A thermostat or hygrostat controlled process is more efficient than a time controlled process.	
1.7	Can the process times and temperatures be adjusted more efficiently?	
1.8	Can more use be made of renewable energy in production or processing?	
2.	**Environmental management**	**Comments**
2.1	Reduce quantities of raw materials to levels where materials will be used up just as new materials are arriving (Just-In-Time production).	
2.2	Do you use all the samples you receive from chemical suppliers (no-used samples are hazardous waste)?	
2.3	Can expired products be returned to its supplier?	
2.4	Do all the suppliers send the Material Safety Data Sheets for all the (new) chemicals that they supply?	
2.5	Can the product or service be combined with others to reduce overall material and energy intensity?	
2.6	Can customers be informed or educated about ways of extending product durability?	
2.7	Can "green" ideas be exchanged between your company, network partners, and other companies in the same industry?	
2.8	Can your industry organisation or other knowledge providing institution provide you with information concerning "green" clients / markets (in present and in the future)?	
2.9	Can changes in the environmental legislation be expected which require changes in the production process?	
2.10	Can funding be obtained from the government (local, regional, national funding programmes) to improve the economic / environmental performance of your company?	
3.	**Inspection / maintenance**	**Comments**
3.1	Can yields be increased by better maintenance, control, or other means? For example: - Are pumps, valves, and pipes inspected regularly to minimise leaks? - Could better maintenance of boilers and other equipment improve energy efficiency? Are the burners of the boilers and dryers cleaned regularly? Are they the right size? - Are all hot and cold transportation pipes isolated? - Are equipment and vehicles properly maintained so that emissions are kept to a minimum?	
3.2	Are supplied products/raw materials inspected as they arrive in your company? Identify why the quality criteria are not met.	

Ref.no.	NETWORK BRAINSTORMING SESSION – COMPANY CHECKLIST	
3.3	Can material use be minimised by improved mechanical design / machinery / equipment?	
4.	**Packaging**	**Comments**
4.1	Can packaging be eliminated or reduced by: - integrating transportation packaging design with product packaging - making products of smaller size, or a different shape - using the packaging more than one time	
4.2	Can the environmental effect of the packaging be reduced?	
4.3	Can product packaging be made more recyclable?	
4.4	Can used packaging be returned to its supplier for recycling and reuse?	
5.	**Process optimisation**	**Comments**
5.1	Can supplied products and raw materials be produced or processed in less materially intense ways?	
5.2	Can water consumption be reduced?	
5.3	Can harmful (toxic) substances be eliminated from production processes and remaining harmful substances be recycled or incinerated?	
5.4	Can more use be made of resources that are certified as being sustainably produced?	
5.5	If the following liquids are used in any manufacturing process, is their use minimised, and have substitutes been investigated? - solvents or oils - organic species of concern - acids - nutrients	
5.6	Do some of the network partners have special requirements which have no effect on the quality of purpose of the products or services, but which have a negative economic/environmental effect on your production process?	
6.	**Product design**	**Comments**
6.1	Can products/services be redesigned/adjusted, so that - less waste is created in later stages - less use of materials and energy inputs is made, also during the user-phase - renewable and abundant materials are used instead of scarce and non-renewable ones - more use is made of recyclable materials/components (material point of view)	
6.2	Can products/services be redesigned/adjusted, so that - end-of-life products can be disassembled easily - end-of-life products are easier to dispose off (end-of-life point of view)	
6.3	Can products/services be redesigned/adjusted, so that - products/components are made modular to allow easy upgrading - longevity of the product or the production equipment/tools is improved - distribution and logistics is made easier (service point of view)	
6.4	Can the product (components) be marked so that the recyclability is made easier (eco-labelling)?	
6.5	Can the properties of the product be accentuated or developed for greater customer value?	
6.6	What services are customers really getting from your product? Can this be provided more effectively or in complete different ways?	

Ref.no.	NETWORK BRAINSTORMING SESSION – COMPANY CHECKLIST	
6.7	What services will customers need in the future? Can you design new or develop existing products to meet them?	
6.8	Is your product providing other services as well as the most obvious one? Can these be accentuated or enhanced? Can the product or service be integrated or synchronised with others to provide multifunctionality?	
7.	**Transport**	**Comments**
7.1	Can transport be reduced or greater use be made of energy-efficient transport such as rail?	
7.2	Can products be transported or distributed by alternative means to enhance customer value and reduce environmental impacts?	
7.3	Can production be localised to both enhance service and reduce transport needs?	
8.	**Wastes**	**Comments**
8.1	Can waste disposal costs be reduced by any way (give in waste more separate, change concentration, other size drums / cans, combine transport with other companies in the region)?	
8.2	Are there any opportunities to recycle, remanufacture or re-use wastes, in- and outside company (participate in waste exchange schemes)?	
8.3	Use processing methods which generate treatable or recyclable waste on-site. Track the non-recyclable waste streams in the company and ask suppliers for alternative products.	
8.4	Can products, which don't meet the quality standards, be reused, remanufactured, or recycled?	
8.5	Can end-of-life products be reused, remanufactured, recycled, or incinerated?	
8.6	Can customer's disposal problems be eliminated by providing a take-back service?	
8.7	Can the wastewater treatment plant treat the wastewater of the related process steps (more efficient)?	
8.8	Can support organisations provide the needed environmental training to employees who deal with hazardous chemicals and wastes? The key to any waste minimisation effort is employee participation. Training and educational programmes can inform employees about waste minimisation and its benefits.	

NETWORK IMPACT MATRIX

UPDATE: [DATE]

NETWORK IMPACT RATINGS FOR: [FUNCTIONAL UNIT]

environmental concerns		rating*	selected products / materials**	environmental stressors	explanation why rating was chosen	reference
Pre-manufacturing: raw material extraction/processing, intermediate product production, assembling, trading						
1,1	material choice for products used in pre-manufacturing processes		selected process chemical no .1			
			selected process chemical no .2			
			etc.			
1,2	energy use during pre-manufacturing processes		selected process chemical no .1			
			selected process chemical no .2			
			etc.			
1,3	solid residue generated during pre-manufacturing processes		selected process chemical no .1			
			selected process chemical no .2			
			etc.			
1,4	liquid residue generated during pre-manufacturing processes		selected process chemical no .1			
			selected process chemical no .2			
			etc.			
1,5	gas residue generated during pre-manufacturing processes		selected process chemical no .1			
			selected process chemical no .2			
			etc.			

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

** selection of products and materials for assessment of the pre-manufacturing phase is based on:
- annual consumption / annual costs / influencability

NETWORK IMPACT MATRIX

UPDATE: [DATE]

NETWORK IMPACT RATINGS FOR: [FUNCTIONAL UNIT]

environmental concerns		rating *	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME					
2,1	material choice for products used in production process of SME		process step no.1		
			process step no.2		
			etc		
2,2	energy use during production process of SME		process step no.1		
			process step no.2		
			etc		
2,3	solid residue generated during production process of SME		process step no.1		
			process step no.2		
			etc		
2,4	liquid residue generated during production process of SME		process step no.1		
			process step no.2		
			etc		
2,5	gas residue generated during production process of SME		process step no.1		
			process step no.2		
			etc		

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

NETWORK IMPACT MATRIX

UPDATE: [DATE]

NETWORK IMPACT RATINGS FOR: [FUNCTIONAL UNIT]

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product packaging and transport (to and from SME)					
3,1	material choice for packaging and transport		incoming products		
			outgoing products		
3,2	energy use during packaging processes and transport		incoming products		
			outgoing products		
3,3	solid residue generated during packaging processes and transport		incoming products		
			outgoing products		
3,4	liquid residue generated during packaging processes and transport		incoming products		
			outgoing products		
3,5	gas residue generated during packaging processes and transport		incoming products		
			outgoing products		

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

NETWORK IMPACT MATRIX

UPDATE: [DATE]

NETWORK IMPACT RATINGS FOR: [FUNCTIONAL UNIT]

	environmental concerns	rating*	subcategory	explanation why rating was chosen	reference
Product handling by first, second and third tier clients					
4,1	material choice for products supporting handling / using phase		first tier clients		
			second tier clients		
			etc.		
4,2	energy use during handling / using product		first tier clients		
			second tier clients		
			etc.		
4,3	solid residue generated during handling / using product		first tier clients		
			second tier clients		
			etc.		
4,4	liquid residue generated during handling / using product		first tier clients		
			second tier clients		
			etc.		
4,5	gas residue generated during handling / using product		first tier clients		
			second tier clients		
			etc.		

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

NETWORK IMPACT MATRIX

NETWORK IMPACT RATINGS FOR: [FUNCTIONAL UNIT]

UPDATE: [DATE]

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies					
5,1	material choice for chemicals used used during recycle / waste treatm. process		waste stream no.1		
			waste stream no.2		
			etc.		
5,2	energy use during recycling / waste treatm. process		waste stream no.1		
			waste stream no.2		
			etc.		
5,3	solid residue generated during recycling / waste treatm. process		waste stream no.1		
			waste stream no.2		
			etc.		
5,4	liquid residue generated during recycling / waste treatm. process		waste stream no.1		
			waste stream no.2		
			etc.		
5,5	gas residue generated during recycling / waste treatm. process		waste stream no.1		
			waste stream no.2		
			etc.		

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

APPENDIX

B Environmentally Responsible Process Matrix: Scoring Guidelines and Protocols

The Process Improvement Matrix is described in Chapter 8. In this appendix, a sample of possible scoring considerations appropriate to each of the matrix elements is presented. It is anticipated that different types of processes may require different check lists and evaluations, so this appendix is presented as an example rather than as a universal formula.

PROCESS MATRIX ELEMENT: 1,1

Life Stage: Resource Provisioning
Environmental Stressor: Materials Choice

If either of the following conditions apply, the matrix element rating is 4

- For the case where supplier components/subsystems are used: No/little information is known about the chemical content in supplied process consumables and equipment.
- For the case where materials are acquired from suppliers: A scarce material is used where a reasonable alternative is available. (Scarce materials are defined as antimony, beryllium, boron, cobalt, chromium, gold, mercury, the platinum metals [Pt, Ir, Os, Pa, Rh, Ru], silver, thorium, and uranium.)

If the following condition applies, the matrix element rating is 0

- No virgin material is used in incoming components or materials.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process meets DFE preferences for this matrix element.

- Is the process designed to minimize the use of materials in restricted supply?
- Is the process designed to utilize recycled materials or components wherever possible?
- Of the potential consumable materials, are those chosen the ones whose extraction results in the lowest environmental impact?

PROCESS MATRIX ELEMENT: 1,2

Life Stage: Resource Provisioning
Environmental Stressor: Energy Use

If the following condition applies, the matrix element rating is 4

- One or more of the principal materials used in the process requires energy-intensive extraction and suitable alternative materials are available that do not. (Materials requiring energy-intensive extraction are defined as virgin aluminum, virgin steel, and virgin petroleum.)

If the following condition applies, the matrix element rating is 0

- Negligible energy is needed to extract or ship the materials or components for this process.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process meets DFE preferences for this matrix element.

- Is the process designed to minimize the use of virgin materials whose extraction is energy intensive?
- Does the process design avoid or minimize the use of high-density materials whose transport to and from the facility will require significant energy use? (Such materials are defined as those with a specific gravity above 7.0.)
- Is transport distance of incoming materials and components minimized?

PROCESS MATRIX ELEMENT: 1,3

Life Stage: Resource Provisioning
Environmental Stressor: Solid Residues

If either of the following conditions apply, the matrix element rating is 4

- For the case where materials are acquired from suppliers: Metals from virgin ores are used, creating substantial waste rock residues that could be avoided by the use of virgin material, and suitable virgin material is available from recycling streams.
- For the case where supplier components/subsystems are used: All incoming packaging is from virgin sources and consists of three or more types of materials.

If all of the following conditions apply, the matrix element rating is 0

- For the case where materials are acquired from suppliers: No solid residues result from resource extraction or during production of materials by recycling (example: petroleum).

- For the case where supplier components/subsystems are used: Minimal or no packaging material is used or the supplier takes back all packaging material.
- For the case where supplier components/subsystems are used: Incoming packaging is totally reused/recycled.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process meets DFE preferences for this matrix element.

- Is the process designed to minimize the use of materials whose extraction or purification involves the production of large amounts of solid residues (i.e., coal and all virgin metals)?
- Is the process designed to minimize the use of materials whose extraction or purification involves the production of toxic solid residues? (This category includes all radioactive materials.)
- Has incoming packaging volume and weight, at and among all levels (primary, secondary, and tertiary), been minimized?
- Is materials diversity minimized in incoming packaging?

PROCESS MATRIX ELEMENT: 1,4

Life Stage: Resource Provisioning
Environmental Stressor: Liquid Residues

If either of the following conditions apply, the matrix element rating is 4

- For the case where supplier components/subsystems are used: Metals from virgin ores that cause substantial acid mine drainage are used, and suitable virgin material is available from recycling streams. (Materials causing acid mine drainage are defined as copper, iron, nickel, lead, and zinc.)
- For the case where materials are acquired from suppliers: The packaging contains toxic or hazardous substances that might leak from it if improper disposal occurs.

If both of the following conditions apply, the matrix element rating is 0

- For the case where materials are acquired from suppliers: No liquid residues result from resource extraction or during production of materials by recycling.
- For the case where supplier components/subsystems are used: No liquid residue is generated during transportation, unpacking, or use of this product.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process meets DFE preferences for this matrix element.

- Is the process designed to minimize the use of materials whose extraction or purification involves the generation of large amounts of liquid residues? (This category includes paper and allied products, coal, and materials from biomass.)
- Is the process designed to minimize the use of materials whose extraction or purification involves the generation of toxic liquid residues? (These materials are defined as aluminum, chromium, copper, iron, lead, mercury, nickel, and zinc.)
- Are refillable/reusable containers used for incoming liquid materials where appropriate?
- Does the use of incoming components require cleaning that involves a large amount of water or that generates liquid residues needing special disposal methods?

PROCESS MATRIX ELEMENT: 1,5

Life Stage: Resource Provisioning
Environmental Stressor: Gaseous Residues

If the following condition applies, the matrix element rating is 4

- The materials used cause substantial emissions of toxic, smog-producing, or greenhouse gases into the environment, and suitable alternatives that do not do so are available. (These materials are defined as aluminum, copper, iron, lead, nickel, zinc, paper and allied products, and concrete.)

If the following condition applies, the matrix element rating is 0

- No gaseous residues are produced during resource extraction or production of materials by recycling.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process meets DFE preferences for this matrix element.

- Is the process designed to minimize the use of materials whose extraction or purification involves the generation of large amounts of gaseous (toxic or otherwise) residues? (Such materials are defined as aluminum, copper, iron, lead, nickel, and zinc.)
- Does the process design avoid using consumable materials whose transport to the facility will result in significant gaseous residues?

PROCESS MATRIX ELEMENT: 2,1

Life Stage: Process Implementation
Environmental Stressor: Materials Choice

If the following condition applies, the matrix element rating is 4

- Process equipment manufacture requires relatively large amounts of materials that are restricted, toxic, and/or radioactive.

If the following condition applies, the matrix element rating is 0

- Materials used in process equipment manufacture are completely closed loop (captured and reused/recycled) with minimum inputs required.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process equipment meets DFE preferences for this matrix element.

- Does the process equipment design avoid the use of materials that are in restricted supply?
- Is the use of toxic material avoided or minimized?
- Is the use of radioactive material avoided?
- Is the use of virgin material minimized?
- Has the chemical treatment of materials and components been minimized?

PROCESS MATRIX ELEMENT: 2,2

Life Stage: Process Implementation
Environmental Stressor: Energy Use

If the following condition applies, the matrix element rating is 4

- Energy use for process equipment manufacture and installation is high and less energy-intensive alternatives are available.

If the following condition applies, the matrix element rating is 0

- Process equipment manufacture and installation requires no or minimal energy use.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process equipment meets DFE preferences for this matrix element.

- Is the process equipment manufacture designed to minimize the use of energy-intensive processing steps?
- Is the process equipment manufacture designed to minimize energy-intensive evaluation/testing steps?
- Does the process equipment manufacture use co-generation, heat exchanges, and/or other techniques to utilize otherwise wasted energy?

PROCESS MATRIX ELEMENT: 2,3

Life Stage: Process Implementation
Environmental Stressor: Solid Residues

If the following condition applies, the matrix element rating is 4

- Solid residues from shipping and installation are large and no reuse/recycling programs are in use.

If the following condition applies, the matrix element rating is 0

- Solid residues from shipping and installation are minor and are >90 percent reused/recycled.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process equipment meets DFE preferences for this matrix element.

- Have solid shipping and installation residues been minimized to the greatest extent possible?
- Has the resale of all solid shipping and installation residues been implemented?

PROCESS MATRIX ELEMENT: 2,4

Life Stage: Process Implementation
Environmental Stressor: Liquid Residues

If the following condition applies, the matrix element rating is 4

- Liquid shipping and installation residues are large and no reuse/recycling programs are in use.

If the following condition applies, the matrix element rating is 0

- Liquid shipping and installation residues are minor and each constituent is >90 percent reused/recycled.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process meets DFE preferences for this matrix element.

- If solvents or oils are used in the shipping and installation of this process equipment, is their use minimized and have alternatives been investigated and implemented?
- If water is used in the shipping and installation of this process equipment, is its use minimized and have alternative approaches been investigated and implemented?

PROCESS MATRIX ELEMENT: 2,5

Life Stage: Process Implementation
Environmental Stressor: Gaseous Residues

If either of the following conditions apply, the matrix element rating is 4

- Gaseous process equipment shipping and installation residues are large and uncontrolled.

- Large amounts of solid residues result from the complementary processes and no control is practiced.

If the following condition applies, the matrix element rating is 0

- No solid residues result from the complementary processes.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the complementary processes meet DFE preferences for this matrix element.

- Have solid complementary process residues (mold scrap, cutting scrap, and so on) been minimized and reused to the greatest extent possible?
- Have opportunities for sale of all complementary process solid residues as inputs into the products and processes of others been investigated, and modifications made to residues (if possible and necessary) to facilitate such transactions?
- Has packaging material entering the facility in connection with complementary processes been minimized, and does it use the fewest possible different materials?
- Do suppliers take back the packaging material in which consumables for complementary processes enter the facility?

PROCESS MATRIX ELEMENT: 4,4

Life Stage: Complementary Process Operation
Environmental Stressor: Liquid Residues

If the following condition applies, the matrix element rating is 4

- Large amounts of liquid residues result from the complementary processes and no control is practiced.

If the following condition applies, the matrix element rating is 0

- No liquid residues result from the complementary processes.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the complementary processes meet DFE preferences for this matrix element.

- If solvents or oils are used in complementary processes, is their use minimized and have substitutes been investigated?
- Have opportunities for sale of all complementary process liquid residues as inputs into the products and processes of others been investigated, and modifications made to residues (if possible and necessary) to facilitate such transactions?
- Have complementary processes been designed to utilize the maximum amount of recycled liquid species rather than virgin materials?

PROCESS MATRIX ELEMENT: 4,5

Life Stage: Complementary Process Operation
Environmental Stressor: Gaseous Residues

If the following condition applies, the matrix element rating is 4

- Large amounts of gaseous residues result from the complementary processes and no control is practiced.

If the following condition applies, the matrix element rating is 0

- No gaseous residues result from the complementary processes.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the complementary processes meet DFE preferences for this matrix element.

- Have opportunities for sale of all complementary process gaseous residues as inputs into the products and processes of others been investigated, and modifications made to residues (if possible and necessary) to facilitate such transactions?
- Are greenhouse gases used or generated in the complementary processes?
- If CFCs or HCFCs are used in complementary processes, have alternatives been thoroughly investigated?

PROCESS MATRIX ELEMENT: 5,1

Life Stage: Refurbishment, Recycling, Disposal
Environmental Stressor: Material Choice

If the following condition applies, the matrix element rating is 4

- Process equipment contains significant quantities of mercury (i.e., mercury relays), asbestos (i.e., asbestos based insulations), or cadmium (i.e., cadmium or zinc plated parts) that are not clearly identified and easily removable.

If the following condition applies, the matrix element rating is 0

- Material diversity is minimized, the product is easy to disassemble, and all parts are recyclable.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process equipment meets DFE preferences for this matrix element.

- Have materials been chosen and used in light of the desired recycling/disposal option for the process equipment (e.g., for incineration, for recycling, for refurbishment)?
- Does the process equipment minimize the number of different materials that are used in its manufacture?
- Are the different materials easy to identify and separate?

- Is this battery-free process equipment?
- Is this process equipment free of components containing PCBs or PCTs (e.g., in capacitors and transformers)?
- Are major plastics parts free of polybrominated flame retardants or heavy metal-based additives (colorants, conductors, stabilizers, etc.)?

PROCESS MATRIX ELEMENT: 5,2

Life Stage: Refurbishment, Recycling, Disposal
Environmental Stressor: Energy Use

If the following condition applies, the matrix element rating is 4

- Recycling/disposal of this process equipment is relatively energy intensive (compared to other products that perform the same function) due to its weight, construction, and/or complexity.

If the following condition applies, the matrix element rating is 0

- Energy use for recycling or disposal of this process equipment is minimal.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process equipment meets DFE preferences for this matrix element.

- Is the process equipment designed with the aim of minimizing the use of energy-intensive steps in disassembly?
- Is the process equipment designed for high-level reuse of materials? (Direct reuse in similar process equipment is preferable to a degraded reuse.)
- Will transport of process equipment for recycling be energy intensive because of process equipment weight or volume or the location of recycling facilities?

PROCESS MATRIX ELEMENT: 5,3

Life Stage: Refurbishment, Recycling, Disposal
Environmental Stressor: Solid Residues

If the following condition applies, the matrix element rating is 4

- Process equipment consists primarily of unrecyclable solid materials (such as rubber, fiberglass, and compound polymers).

If the following condition applies, the matrix element rating is 0

- Process equipment can be easily refurbished and reused and is easily dismantled and 100 percent reused/recycled at the end of its life. For example, no part of this process equipment will end up in a landfill.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process equipment meets DFE preferences for this matrix element.

- Has the process equipment been assembled with fasteners such as clips or hook-and-loop attachments rather than chemical bonds (gels, potting compounds) or welds?
- Have efforts been made to avoid joining dissimilar materials together in ways difficult to reverse?
- Are all plastic components identified by ISO markings as to their content?
- If the process equipment consists of plastic parts, is there one dominant (>80 percent by weight) species?
- Is this process equipment to be leased rather than sold?

PROCESS MATRIX ELEMENT: 5,4

Life Stage: Refurbishment, Recycling, Disposal
Environmental Stressor: Liquid Residues

If the following condition applies, the matrix element rating is 4

- The process equipment contains primarily unrecyclable liquid materials.

If the following condition applies, the matrix element rating is 0

- The process equipment uses no operating liquids (such as oils, coolants, or hydraulic fluids) and no cleaning agents or solvents are necessary for its reconditioning.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process equipment meets DFE preferences for this matrix element.

- Can liquids contained in the process equipment be recovered at disassembly rather than lost?
- Does disassembly, recovery, and reuse generate liquid residues?
- Does materials recovery and reuse generate liquid residues?

PROCESS MATRIX ELEMENT: 5,5

Life Stage: Refurbishment, Recycling, Disposal
Environmental Stressor: Gaseous Residues

If the following condition applies, the matrix element rating is 4

- Process equipment contains or produces primarily unrecyclable gaseous materials that are dissipated to the atmosphere at the end of its life.

If the following condition applies, the matrix element rating is 0

- Process equipment contains no substances lost to evaporation/ sublimation (other than water) and no volatile substances are used for refurbishment.

If neither of the preceding ratings is assigned, complete the checklist below. Assign a rating of 1, 2, or 3 depending on the degree to which the process equipment meets DFE preferences for this matrix element.

- Can gases contained in the process equipment be recovered at disassembly rather than lost?
- Does materials recovery and reuse generate gaseous residues?
- Can plastic parts be incinerated without requiring sophisticated air pollution control devices? Plastic parts that can cause difficulty in this regard are those that contain polybrominated flame retardants or metal-based additives, are finished with polyurethane-based paints, or are plated or painted with metals.

In this Appendix an overview is given of the organisations related to and/or specialised in the South African textile industry. Although it was tried to make this overview as complete as possible, it can not be ensured that all specialised / textile related organisations have been included in the following discussion.

<u>CSIR – Division of Textiles (Textek)</u>

The Council for Scientific and Industrial Research (CSIR) is a community and industry directed scientific and technological research and development organisation. The mission of the CSIR is to provide technology solutions and information to support sustainable development and economic growth in South Africa. The CSIR is divided in 12 divisions covering different research areas. One of the divisions is the Division of Textiles which provides integrated textile, clothing and related technological products, services and solutions in participation with government structures, industry and developing communities to assist micro, small and medium enterprises though innovation and business development. Area's of expertise include: evaluation and development of fibres, yarns and fabrics; mechanical and wet processing of natural fibres and their blends; textile machine and instrument design and development; textile related engineering and production mechanisation and automation. Textek is also involved in textile training / education. The aim of the courses is to improve the operation of the production processes and the product quality.

<u>DTI – Directorate: Textile, Clothing and Footwear (TCF)</u>

The Directorate Textile, Clothing and Footwear of the DTI is responsible for a wide range of activities to assist these three sectors plus the leather sector in South Africa to be competitive. The activities include export promoting programmes, strategy development, tariffs, import control on footwear and worn clothing, trade agreements, but also different kind of programmes to reduce costs and improve productivity of companies.

A joint project is planned (1999/2000) between the Directorate TCF and the CSIR Textek which aims to set environmental standards for the textile industry in South Africa based on international standards. Another partner of the Directorate TCF is the South African Bureau of Standards (SABS) who are implementing the new standard for environmental management systems ISO14001 ao in the textile industry.

So the Directorate TCF's role concerning environmental issues in the textile industry can be summarised as [House, 1999]:

- Encouraging the implementation and certification of an environmental management system according to the international accepted ISO14001 norm;
- Working together with CSIR Textek and SABS on projects related to the improvement of environmental awareness;
- Encouraging industry to access the Directorate TCF's supply-side measures which offer financial assistance to manufacturers to achieve competitiveness, including environment-friendliness;
- Considering environmental concerns in trade agreements;
- Improving the environment-friendliness in the textile industry in South Africa with project funded by overseas countries;
- Considering environmental education in all the training initiatives with the industry.

<u>Textile Federation (Texfed)</u>

The Textile Federation was founded in 1976 with the incorporation of individual trade associations, like the Worsted Manufacturers Association, National Fabric Knitters' Association and the South African Cotton Textile Manufacturers' Association. So Texfed is an umbrella organisation of the trade associations related to the South African textile industry. Textfed aims to provide services to its member by advancing and promoting their trade and trade-related interests. It provides information to a wide range of industry stakeholders and proactively represents the industry on key issues. Textile Federation produces a newsletter, a booklet with annual textile statistics and economic review. A directory and product index is published twice a year. The principle role of Texfed is to create the best possible environment to promote the successful functioning and growth of the textile industry in South Africa. Texfed acts as a spokesperson for members of the industry on key industrial issues and its main concerns are trade issues and changes to legislation that effect the industry.

<u>The Textile Institute (TI)</u>

The Textile Institute is an organisation based in the United Kingdom and is founded in 1910. The Textile Institute has members in 90 countries. In the mid seventies a charter of the Textile Institute was formed in South Africa, but it still operates directly under the umbrella body in the United Kingdom [Barclay, 1997]. The mission of the Textile Institute is to promote professionalism in all areas associated with the textile industries worldwide. Its members come from a range of backgrounds, like research, education, design, fashion, engineering, manufacturing, wholesale and retail distribution, marketing and finance. One of the main benefits of the membership is the opportunity to know members around the world. The national committees provide a programme of activities that are of direct interest and relevance to members. Activities include factory visits, workshops, conferences, seminars and social events.

<u>Clothing Federation (Clofed)</u>

The Clothing Federation is a membership driven non-profit organisation representing the clothing manufacturing industry in South Africa. It is currently supported by the following 4 regional associations:
- Cape Clothing Association (CCA) which covers the Cape Town region;
- Natal Clothing Manufacturers Association (NCMA) which covers the Durban region;
- Transvaal Clothing Manufacturers Association (TCMA) which covers the Johannesburg region;
- Eastern Province Clothing Manufacturers Association (EPCMA) which covers the Port Elisabeth region.

It primarily serves the interest of its members on national issues, working closely together with numerous government departments. Clofed also collects statistics on the industry for analysis and interpretation. Clofed's membership employs approximately 57,000 people, which represents approximately half of the formal employment in the South African clothing industry.

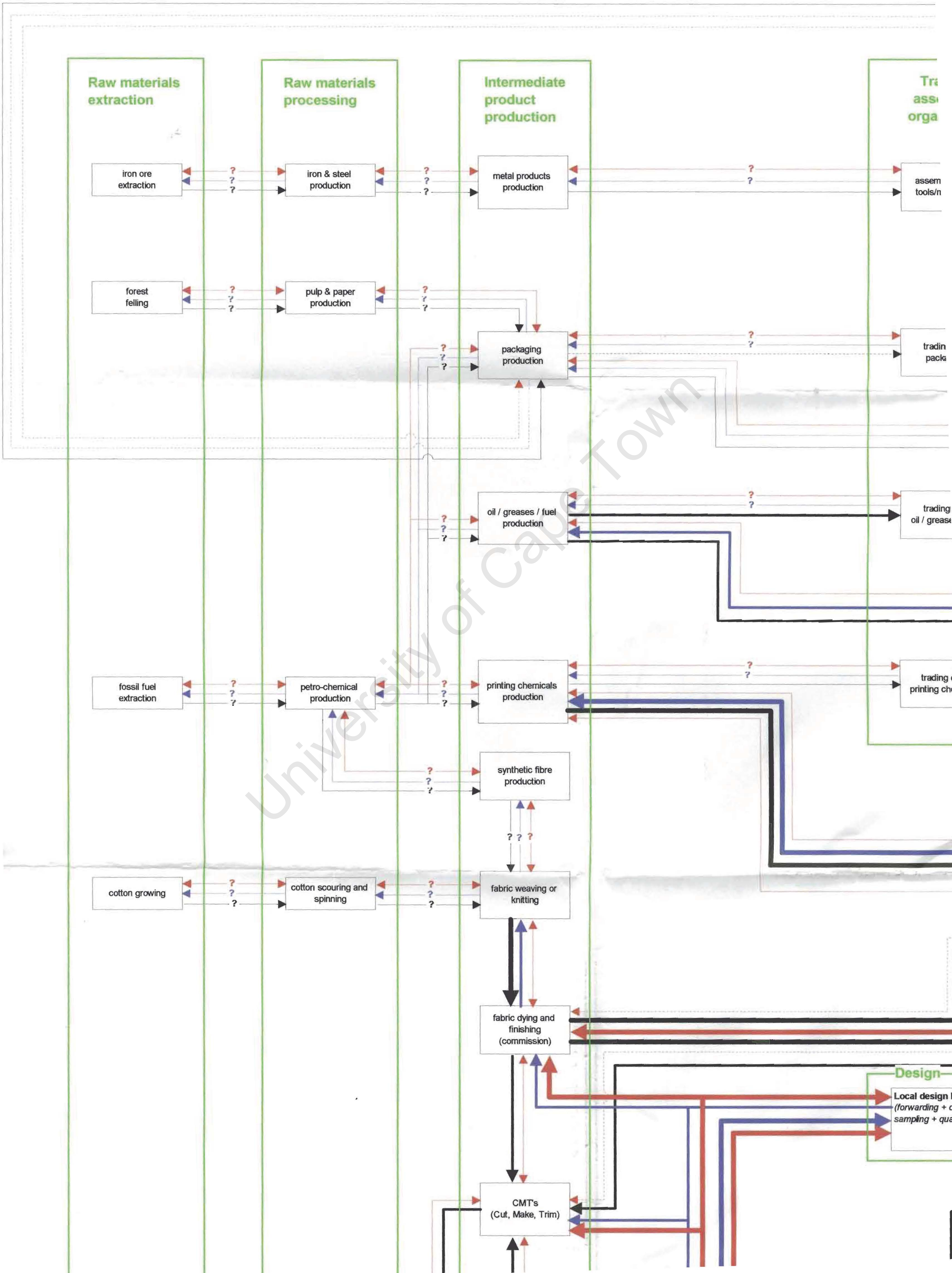
<u>Clotex</u>

Clotex is a clothing and textile service centre for small clothing enterprises, established in 1995, and is based in Cape Town. The aim of Clotex is to enhance the performance of the small and micro clothing enterprises in the Western Cape and to link them with larger producers and retailers. From the outset Clotex has focused its services mainly, but not only, on small and micro enterprises of historically disadvantaged people. The main services it provides are information, advice, mentorship and training. The advice deals mostly with training, sourcing, finance and linkages. Clotex is supported and funded by the Western Cape Provincial Government, the Cape Metropolitan Council, the Ntsika Enterprise Promotion Agency (NEPA) of the Department of Trade and Industry. It has also received a valuable launching fund from Woolworths and other support in natura since the inception. Clotex's aim is to become increasingly financially self-reliant by introducing charges for its services in keeping with the resources of its clients. Clotex is currently in discussions with these organisations in order to expand our services to the medium sized business in order to make a greater impact on the industry as a whole.

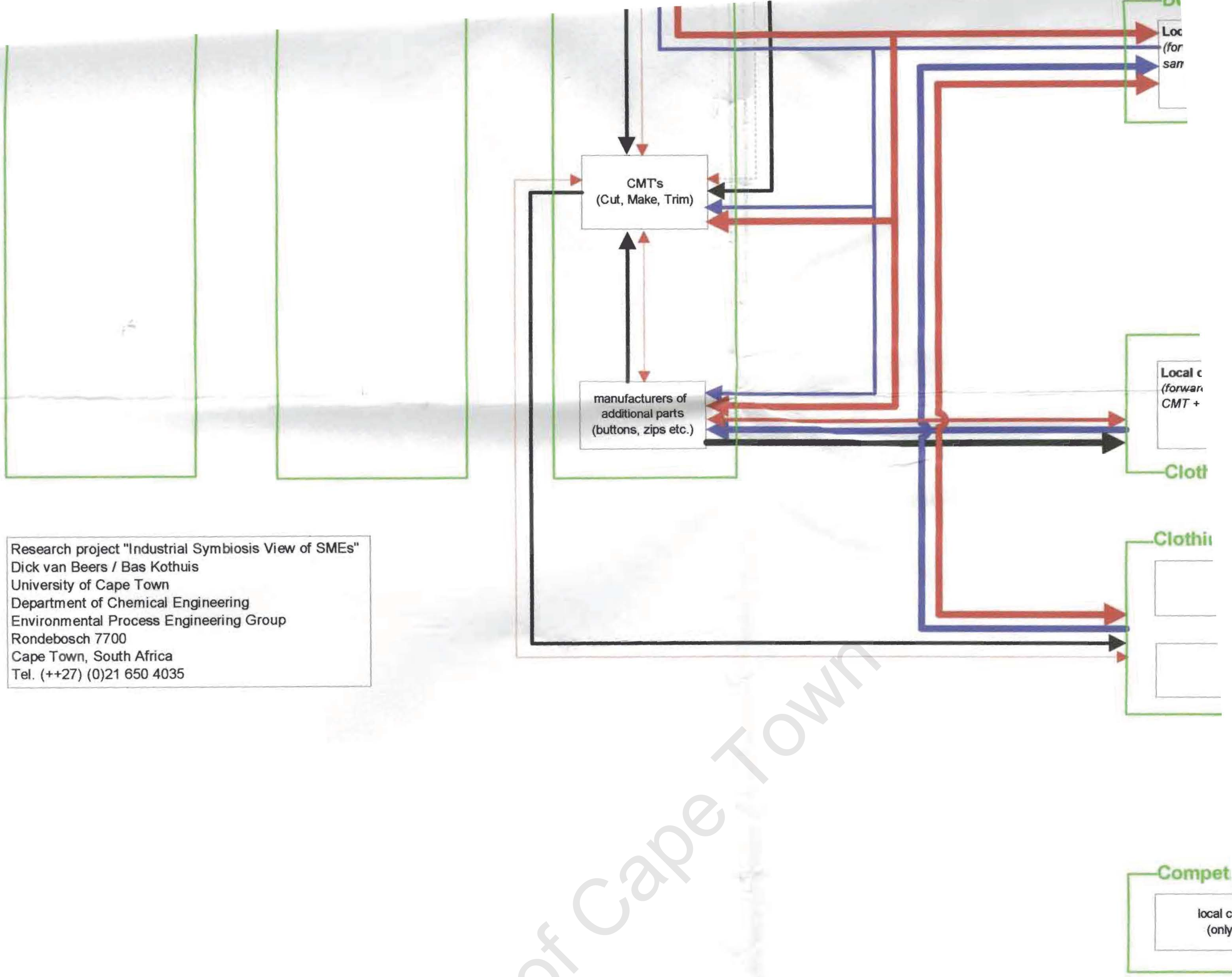
Options for Reduction of Water Consumption at the Textile Printing company [Bakker, 1999]:

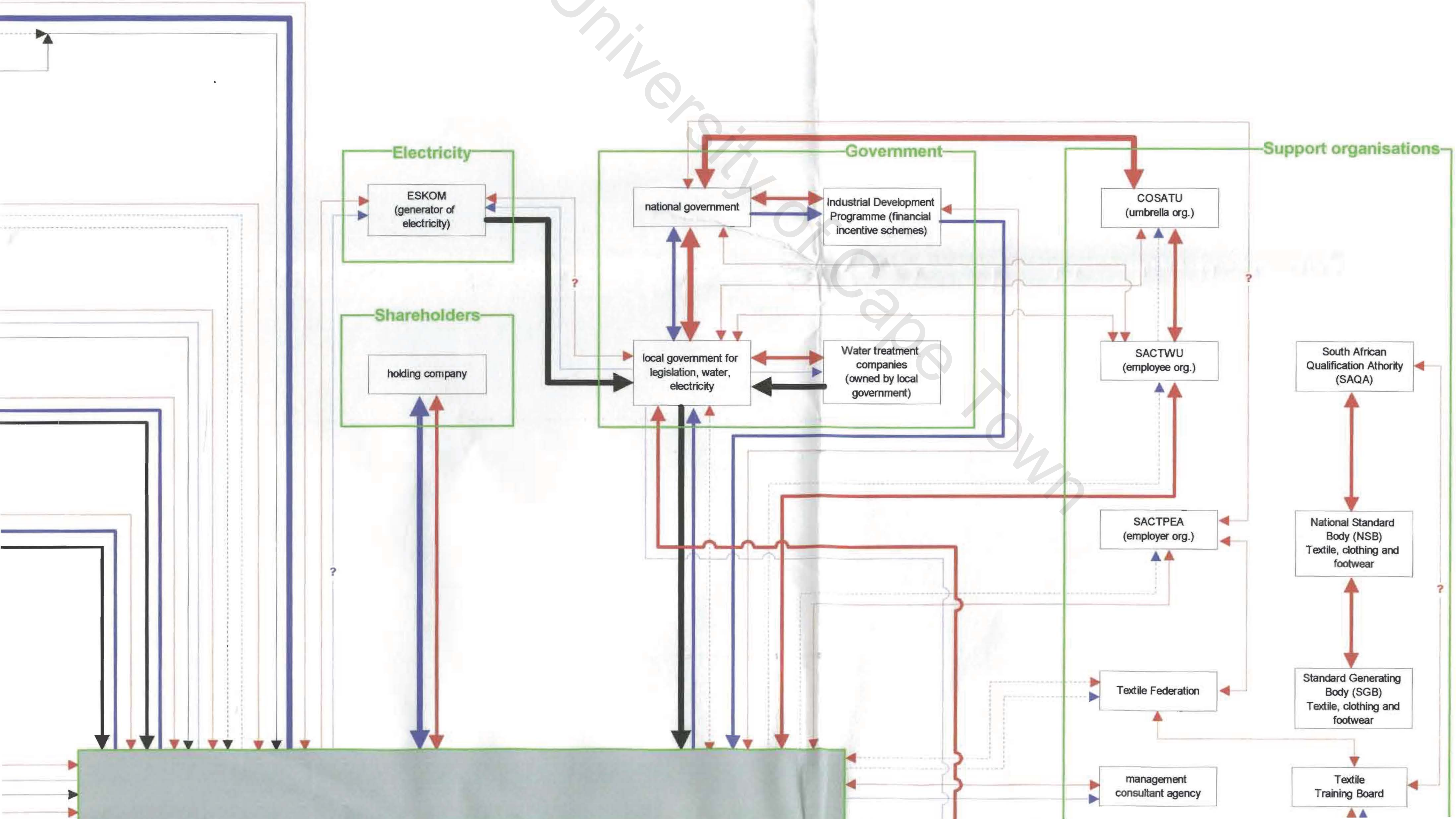
Prevention option		Environmental savings/year	Savings *	Costs
1. Hand pumping at printing machines	Print-paste	5740 Kg	R 22960	R 400
	Water	78 Kl	R 271	
	Total		R23231	
2. Pressure button on the outlet of the hoses	Water	71 Kl	R 249	R 25
3. High pressure hose (wet machine)	Water	1125 Kl	R 3938	R 696
4. Automatic waterstop at printing machine	Water	103 Kl	R 360	R 2500
5. Increase flocculation system and re-use the water	Water	517 Kl	R1810	R774
6. Close the lid of a drum/bucket with left over print-paste airtight	Print-paste			No costs
7. Tap and brush to clean hands	Water	410 Kl	R1435	
8. Hot water tap for cleaning	Water	Less water will be used but energy will be needed to heat the water		R 700 - 1500
Total	Print-paste	5740 Kg	R 22960	R5895
	Water	2304 Kl	R 8063	
	Total		R 31023	

* Calculations are based on: 287 working days a year and ZAR 3.50/Kl water: incoming water = ZAR 2.27; effluent charges = ZAR 1.13 (low estimation)

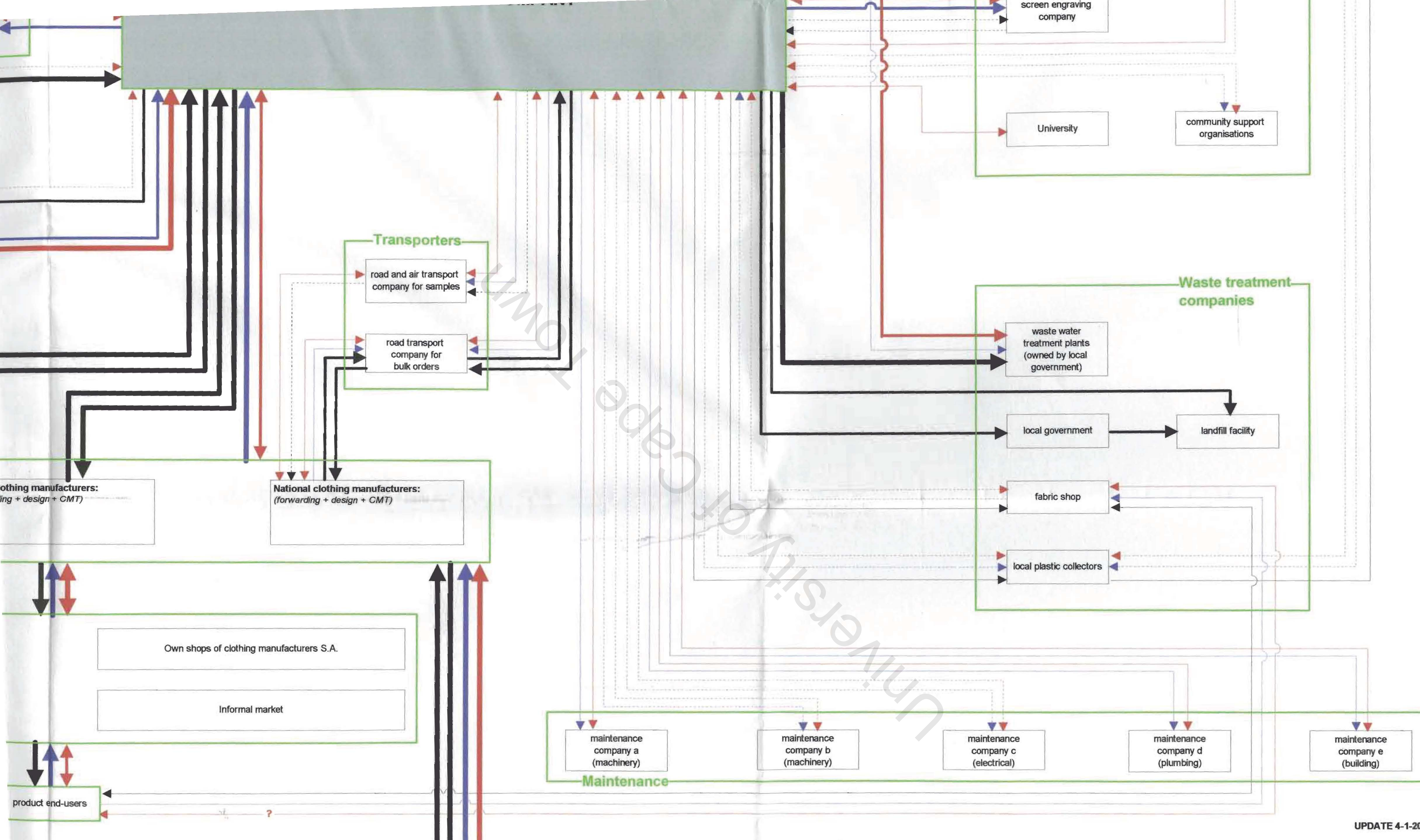


Raw materials extraction
Raw materials processing
Intermediate product production
iron ore extraction
iron & steel production
metal products production
forest felling
pulp & paper production
packaging production
oil / greases / fuel production
fossil fuel extraction
petro-chemical production
printing chemicals production
synthetic fibre production
cotton growing
cotton scouring and spinning
fabric weaving or knitting
fabric dying and finishing (commission)
Design
CMT's (Cut, Make, Trim)


CMT's
(Cut, Make, Trim)
manufacturers of
additional parts
(buttons, zips etc.)
Research project "Industrial Symbiosis View of SMEs"
Dick van Beers / Bas Kothuis
University of Cape Town
Department of Chemical Engineering
Environmental Process Engineering Group
Rondebosch 7700
Cape Town, South Africa
Tel. (++27) (0)21 650 4035



Electricity
ESKOM (generator of electricity)
Shareholders
holding company
Government
national government
Industrial Development Programme (financial incentive schemes)
local government for legislation, water, electricity
Water treatment companies (owned by local government)
Support organisations
COSATU (umbrella org.)
SACTWU (employee org.)
SACTPEA (employer org.)
Textile Federation
management consultant agency
South African Qualification Athority (SAQA)
National Standard Body (NSB) Textile, clothing and footwear
Standard Generating Body (SGB) Textile, clothing and footwear
Textile Training Board
?



UPDATE 4-1-20

flow intensity	material flow [kg/liters/prod. per year]	finance flow [Rands per year]	information flow [personal contact]
very high	> 100,000	> 1,000,000	daily
high	10,000 to 100,000	100,000 to 1,000,000	weekly
medium	1,000 to 10,000	10,000 to 100,000	montly
low	0 to 1,000	0 to 10,000	yearly

FLOW INTENSITY

very high =
high =
medium =
low =

material flow =
finance flow =
information flow =

Ref.no.	NETWORK BRAINSTORMING SESSION – RESULTS TEXTILE PRINTING COMPANY	
1.	**Energy**	**Comments**
1.1	Can waste heat be utilised, exchanged between processes, exchanged between companies?	No. Gas is mainly used for heating. Not much warm water is used in production process.
1.2	Can energy costs be directly allocated to budgets / process steps to encourage better control?	Yes. At the moment there are only a few energy meters installed.
1.3	Is there scope for better energy housekeeping? For example: - Can processes or buildings be insulated more effectively? - Can more energy-efficient lighting be installed? - Are buildings maximising use of passive heating and cooling?	Energy housekeeping for rotary plant is optimal (insulation, energy efficient lighting). Energy housekeeping of flatbed plant can be improved.
1.4	Can raw materials be produced or dried with less or renewable energy?	Yes. Spanish company developed a system to burn less gas by recycling / reusing the hot air in the stenter (curing of the fabric). Spanish company went bankrupt 6 months ago, but the company still has the patent on this technology. No other company can supply this technology.
1.5	Can processes be integrated to create energy savings?	No. Process Textile printing company is already optimised and integrated. Managing director does not see possibilities here.
1.6	Is the drying process managed optimally? Can products be manufactured with less energy? A thermostat or hygrostat controlled process is more efficient than a time controlled process.	Yes. Due to technology and servicing the burners of the stenter are functioning optimally.
1.7	Can the process times and temperatures be adjusted more efficiently?	No. This has already been investigated.
1.8	Can more use be made of renewable energy in production or processing?	Solar power could be investigated for heating purposes. Temperatures above 200 degrees Celsius must be achieved in a short period of time.
2.	**Environmental management**	**Comments**
2.1	Reduce quantities of raw materials to levels where materials will be used up just as new materials are arriving (Just-In-Time production).	Is a possibility. Can be achieved by better planning and support.
2.2	Do you use all the samples you receive from chemical suppliers (no-used samples are hazardous waste)?	Most of samples are fabrics (non-hazardous waste). Samples of dyes and pasta are hazardous waste? → investigate
2.3	Can expired products be returned to its supplier?	Yes, expired products can be returned. The expiry date of products is not really an issue because print paste, dyes, pasta etc. can be stored for a long time (if they are stored correctly)
2.4	Do all the suppliers send the Material Safety Data Sheets for all the (new) chemicals that they supply?	All the chemical suppliers send Material Safety Data Sheets for new products → are kept in file. Except one chemical supplier does not send the data safety sheets. This can be arranged.
2.5	Can the product or service be combined with others to reduce overall material and energy intensity?	Yes. This is already being done. Orders with same colour (combinations) are printed after each other
2.6	Can customers be informed or educated about ways of extending product durability?	Yes, the product end-users can be better informed about washing and handling. But product end-users are not the first tier clients of textile printing company, the clothing manufacturers are. It's the responsibility of the clothing manufacturers, warehouses to educate the product end-users.

Ref.no.	**NETWORK BRAINSTORMING SESSION – RESULTS TEXTILE PRINTING COMPANY**	
2.7	Can "green" ideas be exchanged between your company, network partners, and other companies in the same industry?	Yes. Investigate sharing of waste treatment, exchange waste.
2.8	Can your industry organisation or other knowledge providing institution provide you with information concerning "green" clients / markets (in present and in the future)?	Possibly. Investigate the possibilities (survey?)
2.9	Can changes in the environmental legislation be expected which require changes in the production process?	Yes. Costs of waste treatment and water will increase very much the coming years.
2.10	Can funding be obtained from the government (local, regional, national funding programmes) to improve the economic / environmental performance of your company?	Textile printing company is familiar with the financial support schemes. Are there environmental support schemes? Investigate.
3.	**Inspection / maintenance**	**Comments**
3.1	Can yields be increased by better maintenance, control, or other means? For example: - Are pumps, valves, and pipes inspected regularly to minimise leaks? - Could better maintenance of boilers and other equipment improve energy efficiency? Are the burners of the boilers and dryers cleaned regularly? Are they the right size? - Are all hot and cold transportation pipes isolated? - Are equipment and vehicles properly maintained so that emissions are kept to a minimum?	Not really, equipment used by textile printing company is quite new. Much of the maintenance is done by default, not based on planning. This could be improved (gas burners) There are no hot/cold transportation pipes. Company cars are leased, so they have to be maintained regularly (included in the lease costs).
3.2	Are supplied products/raw materials inspected as they arrive in your company? Identify why the quality criteria are not met.	No. This is not needed for the supplied chemicals (no problems). About 20% of the supplied fabrics by the clients don't meet the quality criteria of textile printing company. The clients are contacted if they are problems with the fabric (will cause bad printing quality) → deal will be made or printing will be stopped. Textile printing company is not in position to demand excellent fabric quality from clients (client – customer relationship).
3.3	Can material use be minimised by improved mechanical design / machinery / equipment?	No. Textile printing company uses modern technology and equipment.
4.	**Packaging**	**Comments**
4.1	Can packaging be eliminated or reduced by: - integrating transportation packaging design with product packaging - making products of smaller size, or a different shape - using the packaging more than one time	Transportation packaging can be integrated with product packaging. Bins/container would be a good idea for bulk, but not for small orders. Printed fabric / end product can be made of smaller size. It's good idea to use fabric packaging (plastic + wooden poles) more than one time → investigate
4.2	Can the environmental effect of the packaging be reduced?	Yes, by recycling the plastic → is already being done.
4.3	Can product packaging be made more recyclable?	No. Plastic is already collected for recycling externally. Wooden poles (to wind up fabric) are also re-used.
4.4	Can used packaging be returned to its supplier for recycling and reuse?	Yes. This is already being done (if this is possible).
5.	**Process optimisation**	**Comments**
5.1	Can supplied products and raw materials be produced or processed in less materially intense ways?	Yes, but very minimally → due to modern technology / equipment.

Ref.no.	NETWORK BRAINSTORMING SESSION – RESULTS TEXTILE PRINTING COMPANY	
5.2	Can water consumption be reduced?	Yes, was part of water consumption project.
5.3	Can harmful (toxic) substances be eliminated from production processes and remaining harmful substances be recycled or incinerated?	Perhaps, but have to know which chemicals it concerns (probably ammonia and screen wash) and how it can be done. See material safety sheets. Contact suppliers for alternative products.
5.4	Can more use be made of resources that are certified as being sustainably produced?	???. Contact suppliers for possibilities?
5.5	If the following liquids are used in any manufacturing process, is their use minimised, and have substitutes been investigated? - solvents or oils - organic species of concern - acids - nutrients	There are perhaps possibilities for replacing the white spirits (as solvent for print paste) used at the flatbed plant. White spirits are used as solvents because it makes the print paste to dry quickly. Look for alternatives. Rotary plant already uses water based print pastes.
5.6	Do some of the network partners have special requirements which have no effect on the quality of purpose of the products or services, but which have a negative economic/environmental effect on your production process?	Some (potential) clients ask the textile printing company to print with Plastisol inks. Textile printing company does not print with these inks because Plastisol inks are really bad for the environment (strong solvents).
6.	**Product design**	**Comments**
6.1	Can products/services be redesigned/adjusted, so that: - less waste is created in later stages - less use of materials and energy inputs is made, also during the user-phase - renewable and abundant materials are used instead of scarce and non-renewable ones - more use is made of recyclable materials/components (material point of view)	Yes, this can be done by printing with recycled or less polluting inks, printing on organic cotton or other fabrics. Textile printing company doesn't have much influence on which fabric and inks are used, this is determined by the clients (the clothing manufacturers). Minerva can supply "environmental friendly" print pastes but these are more expensive and the quality is less. Textile printing company already informed their clients about these inks, but clients are not interested (price, quality).
6.2	Can products/services be redesigned/adjusted, so that - end-of-life products can be disassembled easily - end-of-life products are easier to dispose off - (end-of-life point of view)	Question is not applicable for the textile industry.
6.3	Can products/services be redesigned/adjusted, so that - products/components are made modular to allow easy upgrading - longevity of the product or the production equipment/tools is improved - distribution and logistics is made easier (service point of view)	Upgrading of textile products is not possible. Longevity of the fabric can be improved by better handling and washing (see point 2.6) Improve logistics???
6.4	Can the product (components) be marked so that the recyclability is made easier (eco-labelling)?	Investigate if eco-labelling can expand the market for Textile printing company.
6.5	Can the properties of the product be accentuated or developed for greater customer value?	No ideas.
6.6	What services are customers really getting from your product? Can this be provided more effectively or in complete different ways?	Yes, by using different painting techniques. Textile printing company already investigated the possibilities of ink-jet printing (small orders..
6.7	What services will customers need in the future? Can you design new or develop existing products to meet them?	In future clients will ask for: - more colours - better quality - smaller runs - quicker turnarounds

NETWORK IMPACT MATRIX

UPDATE: 20 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 PRINTED FABRIC (THE ROTARY PLANT)

environmental concerns		rating*	selected products / materials**	environmental stressors	explanation why rating was chosen	reference
Pre-manufacturing: raw material extraction/processing, intermediate product production, assembling, trading						
1,1	material choice for products used in pre-manufacturing processes	2?	glue to stick fabric on blanket rotary printer	polyvinyl alcohol (PVA), 2.5-6% methanol	PVA is made from vinyl acetate, vinyl acetate is made from crude oil? Solvents are used as process chemicals during production process of PVA. Methanol is made from coal, **produced by SASOL South Africa?**	Kirk-Othmer encyclopedia, brainstorming session with Industrial Symbiosis project leader and UCT supervisor
		N.A.	dissolving liquid for glue, used to remove metal ring from rotary screen after printing	formula on the basis of solvents, dichloromethane and organic acid	Glue has already been selected for elimination during the network assessment of phase 2 (Product F4manufacturing by SME).	N.A.
		4	screenwash to clean rotary screens	???	Waiting for info chemical composition from supplier. No/little information is is know about the chemical content of the rotary screenwash.	waiting for information chemical composition screenwash from supplier
		N.A.	pigments and pasta components	see overview "Used Chemicals by textile printing company"	Find less hazardous alternatives for used hazarous chemicals --> see phase 2 of network assessment (Product manufacturing by SME).	N.A.
		2	rotary screens	Nickel	Nickel is not a scarce raw material and is recyclable. Nickel is extracted in South Africa, mostly associated with platinum metals.	Kirk-Othmer encyclopedia
1,2	energy use during pre-manufacturing processes	2?	glue to stick fabric on blanket rotary printer	polyvinyl alcohol (PVA), 2.5-6% methanol	The most energy intensive processes of PVA production are the stripping of the monomer, drying of product and transport (assumed is that PVA is not manufactured in South Africa). The most energy intensive process of methal production is coal gasification.	Kirk-Othmer encyclopedia, brainstorming session with Industrial Symbiosis project leader and UCT supervisor
		N.A.	dissolving liquid for glue, used to remove metal ring from rotary screen after printing	formula on the basis of solvents, dichloromethane and organic acid	Glue has already been selected for elimination during the network assessment of phase 2 (Product manufacturing by SME).	N.A.
		4	screenwash to clean rotary screens	???	Waiting for info chemical composition from supplier. No/little information is is know about the chemical content of the rotary screenwash.	waiting for information chemical composition screenwash from supplier
		N.A.	pigments and pasta components	see overview "Used Chemicals by textile printing company"	Find less hazardous alternatives for used hazarous chemicals --> see phase 2 of network assessment (Product manufacturing by SME).	N.A.

environmental concerns		rating*	selected products / materials**	environmental stressors	explanation why rating was chosen	reference
Pre-manufacturing: raw material extraction/processing, intermediate product production, assembling, trading						
		3	rotary screens	Nickel	Pyrometallurgical and electrolytic processes are used to manufacture Nickel(oxide), these are very energy-intensive processes.	Kirk-Othmer encyclopedia
1,3	solid residue generated during pre-manufacturing processes	2?	glue to stick fabric on blanket rotary printer	polyvinyl alcohol (PVA), 2.5-6% methanol	Assumed is that no or less solid residue are generated during the production of PVA. Ash is generated during the production of methanol.	Kirk-Othmer encyclopedia, brainstorming session with Industrial Symbiosis project leader and UCT supervisor
		N.A.	dissolving liquid for glue, used to remove metal ring from rotary screen after printing	formula on the basis of solvents, dichloromethane and organic acid	Glue has already been selected for elimination during the network assessment of phase 2 (Product manufacturing by SME).	N.A.
		4	screenwash to clean rotary screens	???	Waiting for info chemical composition from supplier. No/little information is is know about the chemical content of the rotary screenwash.	waiting for information chemical composition screenwash from supplier
		N.A.	pigments and pasta components	various, see summary of used chemicals (not included)	Find less hazardous alternatives for used hazarous chemicals --> see phase 2 of network assessment (Product manufacturing by SME).	N.A.
		2?	rotary screens	Nickel	Slag containing iron oxide and other oxide compounds are generated during Nickel extraction process. This slag is used for the manufacturing of iron.	Kirk-Othmer encyclopedia
1,4	liquid residue generated during pre-manufacturing processes	0?	glue to stick fabric on blanket rotary printer	polyvinyl alcohol (PVA), 2.5-6% methanol	Assumed is that no or less liquid residue is generated during the production of PVA and methanol.	Kirk-Othmer encyclopedia, brainstorming session with Industrial Symbiosis project leader and UCT supervisor
		N.A.	dissolving liquid for glue, used to remove metal ring from rotary screen after printing	formula on the basis of solvents, dichloromethane and organic acid	Glue has already been selected for elimination during the network assessment of phase 2 (Product manufacturing by SME).	N.A.
		4	screenwash to clean rotary screens	???	Waiting for info chemical composition from supplier. No/little information is is know about the chemical content of the rotary screenwash.	waiting for information chemical composition screenwash from supplier
		N.A.	pigments and pasta components	see overview "Used Chemicals by textile printing company"	Find less hazardous alternatives for used hazarous chemicals --> see phase 2 of network assessment (Product manufacturing by SME).	N.A.
		4	rotary screens	Nickel	Nickel is a raw material that causes acid mine drainage.	Kirk-Othmer encyclopedia

environmental concerns		rating*	selected products / materials**	environmental stressors	explanation why rating was chosen	reference
Pre-manufacturing: raw material extraction/processing, intermediate product production, assembling, trading						
1,5	gas residue generated during pre-manufacturing processes	3?	glue to stick fabric on blanket rotary printer	polyvinyl alcohol (PVA), 2.5-6% methanol	Solvent emssions are generated during the production of PVA. The following gaseous residues are generated during the production of methanol: H_2S, SOx and CO_2. Methanol production contributes to smog and odour generation.	Kirk-Othmer encyclopedia, brainstorming session with Industrial Symbiosis project leader and UCT supervisor
		N.A.	dissolving liquid for glue, used to remove metal ring from rotary screen after printing	formula on the basis of solvents, dichloromethane and organic acid	Glue has already been selected for elimination during the network assessment of phase 2 (Product manufacturing by SME).	N.A.
		4	screenwash to clean rotary screens	???	Waiting for info chemical composition from supplier. No/little information is is know about the chemical content of the rotary screenwash.	waiting for information chemical composition screenwash from supplier
		N.A.	pigments and pasta components	see overview "Used Chemicals by textile printing company"	Find less hazardous alternatives for used hazarous chemicals --> see phase 2 of network assessment (Product manufacturing by SME).	N.A.
		3 or 4?	rotary screens	Nickel	Large amounts of sulphur dioxide is generated during manufacturing process of Nickel.	Kirk-Othmer encyclopedia

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To assess the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

** selection of products and materials for assessment of the pre-manufacturing phase is based on:
- annual consumption
- annual costs
- influencability

NETWORK IMPACT MATRIX

UPDATE: 20 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 PRINTED FABRIC (THE ROTARY PLANT)

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME					
2,1	material choice for products used in production process of SME	2	pre-press	Nickel is used for rotary screens. Rotary screens are emulsified and engraved by external engraving company. Nickel screens can be used for 4 times and is then recycled externally.	textile printing company info, personal observations
		1 to 2	printing	Most pigments and pasta components used are considered as not hazardous during printing/user phase. Although most chemicals used require a waste treatment plant. **Assess the print paste components on hazardous nature. Thickeners contains white spirits --> alternatives?.** If it is possible, "old" print pastes are reused / updated into new print pastes. Fabric is made of cotton, **no organic cotton is used?**	textile printing company info, info Material Safety Data Sheets, personal observations
		1	after-press	Gas is used for curing and stentering of fabric, diesel was used in the past.	textile printing company info, personal observations
2,2	energy use during production process of SME	0	pre-press	Prepress operations are mainly done manually, not automatically. Less energy is used during pre-press process.	textile printing company info, personal observations
		2 to 3	printing	Rotary printers work on electricity. Printing process is energy-intensive, but efficient due to new technologies. Printing machines are powered down when not in use.	textile printing company info, personal observations
		2 to 3	after-press	Curing and stentering work on gas and electricity. Curing and stentering are energy-intensive processes, but machines are energy-efficient due to new technologies. **Can waste heat be utilised in any way?** Stentering and curing machine are powered down when not in use.	textile printing company info, personal observations
2,3	solid residue generated during production process of SME	1 to 2	pre-press	Solid residues are generated during the print preparation process. These solid residues contain mainly pigments, pasta components, waste print pastes and are disposed as hazardous wastes (dumped on landfill site). **External use of "old" print pastes possible?**	textile printing company info, personal observations
		1 to 2	printing	If it is possible, waste print pastes are used to make new print pastes. This depends on the colour,pasta composition & design. Print pastes are disposed as hazardous waste if re-using is not possible (dumped on landfill site). Misprints (waste fabric) are sold to fabric shop.	textile printing company info, personal observations
		0	after-press	No solid residue is generated during curing and stentering.	textile printing company info, personal observations
2,4	liquid residue generated during production process of SME	3	pre-press	Contaminated waste water is generated because of cleaning purposes after prepation of the print paste. Water is contaminated with mainly print pastes. **What is done with waste dissolving glue --> check amounts, look at process**	textile printing company info, personal observations

environmental concerns		rating *	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME					
		3	printing	Large quantities of water are flowing into the sewer during the printing process. Water is used to clean the blanket of rotary printers. Water is contaminated with mainly print pastes. Waste water settling tank has been installed, but can only treat 25% of waste water produced.	textile printing company info, personal observations
		3 to 4	after-press	Large quantities of water are used to clean the rotary screens after printing. Water is contaminated with mainly print pastes and screenwash. Screenwash is a hazardous chemical which is used to remove the emulsion from the rotary screens. Dissolving liquid for glue is hazardous and expensive. **Find alternative system to connect metal ring to rotary screen?** Waste water settling tank has been installed, but can only treat 25% of waste water produced. **Take notice that the concentration of pigments in waste water, and therewith the COD level, will increase if the water consumption is minimised. See the new formula of the CMC for effluent charges.**	textile printing company info, personal observations
2,5	gas residue generated during production process of SME	0	pre-press	No gaseous residue is generated during the pre-press phase.	textile printing company info, personal observations
		0?	printing	No gaseous residue is generated during the rotary printing process. **Toxicity print pastes?**	textile printing company info, personal observations
		0?	after-press	Gas emissions are generated during curing and stentering, both machines work on gas. These gas emissions are related to energy production --> included in rating energy use 2.2. **Toxicity of screenwash?**	textile printing company info, personal observations

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To assess the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

NETWORK IMPACT MATRIX

UPDATE: 20 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 PRINTED FABRIC (THE ROTARY PLANT)

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product packaging and transport (to and from SME)					
3,1	material choice for packaging and transport	2?	supplied chemicals	Most chemicals are supplied in plastic cans. Empty cans are used to put in the coloured pastes. What kind of plastic is used? The 1-ton containers, in which the supplied binders are stored, are taken back by the supplier, textile printing company gets price product.	textile printing company info, personal observations
		2	fabric	New plastic foil is used to pack printed fabric, waste plastic foil (coming from incoming fabric) is recycled externally. **What kind of plastic is used?**	textile printing company info, personal observations
3,2	energy use during packaging processes and transport	2 to 3	supplied chemicals	Main supplier is Italian company (Minerva), transport mainly by ship + truck. If order is urgent: transport by plane + truck.	textile printing company info, personal observations
		1	fabric	Locally produced plastic, **out of virgin & recycled materials???** Transport by truck.	textile printing company info, personal observations
3,3	solid residue generated during packaging processes and transport	2?	supplied chemicals	About 75% of the supplied cans have a plastic bag inside, so plastic can will not get contaminated. Contaminated plastic bag (with supplied chemical) is disposed to landfill site as hazardous waste. **Is any empty packaging not re-used or recycled? Are arrangements made to take back product packaging for reuse and/or recycling? Is materials diversity minimised in outgoing product packaging?**	textile printing company info, personal observations
		1	fabric	Incoming plastic foil is recyclable and recycled externally. Outgoing plastic foil (goes to client) is recyclable, not every client will recycle plastic. **Contact clients to recycle plastic packaging, or permission to wrap fabric with "old" plastic.**	textile printing company info, personal observations
3,4	liquid residue generated during packaging processes and transport	1 to 2	supplied chemicals	The empty cans are contaminated with the content chemical. Cans which don't have plastic bag inside, are cleaned with a lot of water before internal re-use. **Contact suppliers to use plastic bags inside cans for all supplied chemicals where appropriate? Are refillable or reusable containers used for liquid products where appropriate?**	textile printing company info, personal observations
		0	fabric	No liquid residue is generated during packaging and transportation.	textile printing company info, personal observations

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product packaging and transport (to and from SME)					
3,5	gas residue generated during packaging processes and transport	1 to 2	supplied chemicals	Gas emissions are generated during transport by ship, plane (long distance) and truck (short distance). Transport by ship relatively clean compared to transport by air. **What is the condition of the trucks (old, polluting)?**	textile printing company info, personal observations
		1	fabric	Diesel emissions are generated during transport. Transport of fabric is done by truck. **What is the condition of the trucks (old, polluting)?**	textile printing company info, personal observations

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To assess the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

NETWORK IMPACT MATRIX

UPDATE: 20 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 PRINTED FABRIC (THE ROTARY PLANT)

environmental concerns		rating *	subcategory	explanation why rating was chosen	reference
Product handling by first, second and third tier clients					
4,1	material choice for products supporting handling / using phase	3	design houses (designing, forwarding, sampling)	Clothing retailers have a great influence which textile/clothing processing companies can do the job for them, mainly driven on quality, price and flexibility. Environment is not a criteria to select a textile/clothing processing company or supplier. Standard of environmental management and awareness is low. **Improve environmental awareness. Use eco-labelling as a niche-market. Used packaging in client-part of the network?**	interviews with clients textile printing company
		3	clothing manufacturers (designing, CMT, knitting, forwarding)	Interviewed design houses are not, or only into a less extent, familiar with the concept of eco-labelling and the production of organic cotton. Design houses have a great influence which textile/clothing processing companies can do the job for them, mainly driven on price, turn-around time and quality. Environment is not a criteria to select a textile/clothing processing company or supplier. Standard of environmental management and awareness is low. **Improve environmental awareness. Use eco-labelling as a niche-market. Used packaging in client-part of the network?**	interviews with clients textile printing company
		1	clothing retailers	Clothing manufacturers get orders (read: fabric) from design houses and clothing retailers. **Used packaging in client-part of the network?**	Personal observations (network mapping exercise)
		2	product end-users	No or limited interest from the South African product end-users for eco-friendly clothing, environmental awareness is low. Environmental awareness of overseas consumers is higher, interest in eco-labelled textiles is slowly increasing in Europe. Range of eco-labelled textiles products is still limited. **Used packaging in client-part of the network? Who / what determines washing / handling requirements?**	report "Milieuvriendelijke kleding & de rol van de detailhandel" [Diehl, 1994]
4,2	energy use during handling / using product	3	design houses (designing, forwarding, sampling)	Transport of fabric to and from the different textile and clothing companies is the most energy-intensive activity of design-houses. There are no in-house production processes. Total costs of lighting and air conditioning can be up to 5% of turn-over. **Investigate transport efficiency and standards within network?**	interviews with clients textile printing company
		1	clothing manufacturers (designing, CMT, knitting, forwarding)	Transport of fabric to and from the different textile and clothing companies is the most energy-intensive activity of clothing retailers. There are no in-house production processes. **Investigate transport efficiency and standards within network?**	interviews with clients textile printing company
		1	clothing retailers	CMT is mainly a mechanical process which work on electricity.	book "Environmental Assessment of Textiles" [Laursen et al., 1997]

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product handling by first, second and third tier clients					
		3 to 4	product end-users	Total energy consumption during washing, drying and ironing of fabric is very high (assumed that fabric is washed, dried and ironed every time it is worn). Washing on 60 degrees Celcius instead of 40 degrees Celcius uses twice as much energy. Proper washing instructions can reduce the environmental impact. Because of the high impact of the user phase synthetic fibres or mixed textile fibres are preferable (e.g. cotton-polyester). These kind of fibres are easier to dry and iron. **Education of product end-users by clothing retailers on energy savings during users-phase? Who / what determines washing / handling requirements?**	report "Milieuvriendelijke kleding & de rol van de detailhandel" [Diehl, 1994]
4,3	solid residue generated during handling / using product	3	design houses (designing, forwarding, sampling)	Waste packaging (plastic, cardboard, hangers) is the main solid waste stream for clothing retailers. If it is possible hangers are re-used and waste plastic, cardboard is recycled. Clothing retailers don't have in-house manufacturing processes. But clothing retailers have large influence on who will produce, dye and print and CMT the fabric. So indirectly, they generate solids residues.	interviews with clients textile printing company
		2 to 3	clothing manufacturers (designing, CMT, knitting, forwarding)	Except packaging, no or less solid residue is generated by design houses directly. But design houses have large influence on who will produce, dye and print and CMT the fabric. So indirectly, they generate solids residues.	interviews with clients textile printing company
		2	clothing retailers	Wastes from off-cuts are generated. **Are these off-cuts reused?** Dust is also generated during CMT activities.	book "Environmental Assessment of Textiles" [Laursen et al., 1997]
		1 to 2	product end-users	Waste textiles are eventually thrown away as domestic waste. **What is the impact of used textile chemicals (attached to textile product) after disposal?**	report "Milieuvriendelijke kleding & de rol van de detailhandel" [Diehl, 1994]
4,4	liquid residue generated during handling / using product	0	design houses (designing, forwarding, sampling)	No or less liquid residue is generated by design houses directly. But design houses have large influence on who will produce, dye and print and CMT the fabric. So indirectly, they generate liqued residues.	interviews with clients textile printing company
		1	clothing manufacturers (designing, CMT, knitting, forwarding)	CMT is mainly a mechanical process. Besides from some water used in steam pressing, no or less water is used or waste water is generated.	book "Environmental Assessment of Textiles" [Laursen et al., 1997]
		0	clothing retailers	No or less liquid residue is generated by clothing retailers directly. But clothing retailers have large influence on who will produce, dye and print and CMT the fabric. So indirectly, they generate liqued residues.	interviews with clients textile printing company
		4	product end-users	Amount of waste water, generated during washing, is high (assumed that fabric is washed every time it is worn). Waste water is polluted with washing detergents and washed out pigments/dyes. **Education of product end-users by clothing retailers on water savings during users-phase? Who / what determines washing / handling requirements?**	report "Milieuvriendelijke kleding & de rol van de detailhandel" [Diehl, 1994]

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product handling by first, second and third tier clients					
4,5	gas residue generated during handling / using product	2	design houses (designing, forwarding, sampling)	Gaseous residue is generated during transport activities by clothing retailers. **How are products transported?** Clothing retailers don't have in-house manufacturing processes, but have large influence on who will produce, dye and print and CMT the fabric. So indirectly, they generate gaseous residues.	interviews with clients textile printing company
		2	clothing manufacturers (designing, CMT, knitting, forwarding)	Gaseous residue is generated during transport activities by design houses. **How are products transported?** Design houses don't have in-house manufacturing processes, but have large influence on who will produce, dye and print and CMT the fabric. So indirectly, they generate gaseous residues.	interviews with clients textile printing company
		2	clothing retailers	Exhaust air from steam processing may contain traces from chemicals added in former process (fabric dying and finishing). **Stain removers containing chlorinated products?**	book "Environmental Assessment of Textiles" [Laursen et al., 1997]
		0	product end-users	No or less gaseous residue is generated during the handling or using of the fabric by the product end-users.	report "Milieuvriendelijke kleding & de rol van de detailhandel" [Diehl, 1994]

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To assess the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

NETWORK IMPACT MATRIX

UPDATE: 20 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 PRINTED FABRIC (THE ROTARY PLANT)

	environmental concerns	rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies					
5,1	material choice for chemicals used used during recycle / waste treatm. process	2?	sludge	50% of sludge is old non-reusable coloured paste, other 50% is waste process chemicals. Sludge is disposed on Landfill Facility, owned by local government. Landfill site of commercial waste treatment company better quality? No treatment before disposal. Sludge is stored in plastic cans (re-used cans supplied chemicals). Better seperation possible?	textile printing company info
		1	effluent	Sedimentation and biological bacteria are used to treat industrial and domestic waste water. No or less process chemicals are used.	interview with local government, Kirk-Othmer Encyclopedia
		1	Nickel screens	End-of-life rotary screens are sold by screen engraving company to scrap companies for recycling. Nickel recycling is done by melting the Nickel. No or less process chemicals are used.	information from external engraving company, Kirk-Othmer Encyclopedia
		0 to 1	misprints	Misprints are sold to a fabric shop, they sell it to people who want to make their own clothing.	textile printing company info
		2?	general industrial waste	Collected by local government, disposed on landfill facility. No treatment before disposal. **Components general industrial waste textile printing company --> better purposes?**	textile printing company info
5,2	energy use during recycling / waste treatm. process	0	sludge	50% of sludge is old non-reusable coloured paste, other 50% is waste process chemicals. Sludge is disposed on landfill facility, owned by local government. Landfill site of commercial waste treatment company better quality? No treatment before disposal. Sludge is stored in plastic cans (re-used cans supplied chemicals).	textile printing company info
		2	effluent	Combination of mechanic and biochemical processes are used to treat waste water. Transporting water and generating hot air for the aerotion process are the most energy intensive processes.	interview with local government, Kirk-Othmer Encyclopedia
		2	Nickel screens	End-of-life rotary screens are sold by screen engraving company to scrap companies for recycling. Nickel recycling is done by melting the Nickel. No or less process chemicals are used.	information from external engraving company, Kirk-Othmer Encyclopedia
		0	misprints	Misprints are sold to a fabric shop, they sell it to people who want to make their own clothing. No or less energy used.	textile printing company info
		0 to 1	general industrial waste	Collected by local government, disposed on landfill facility. No treatment before disposal. **Components general industrial waste textile printing company --> better purposes?**	textile printing company info
5,3	solid residue generated during recycling / waste treatm. process	4	sludge	50% of sludge is old non-reusable coloured paste, other 50% is waste process chemicals. Sludge is disposed on landfill facility, owned by local government. Landfill site of commercial waste treatment company better quality? No treatment before disposal. Sludge is stored in plastic cans (re-used cans supplied chemicals).	textile printing company info

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies					
		1	effluent	Sludge is generated during waste water treatment process. This sludge is given away to farmers etc. to fertilise their land. Solid waste is also seperated from the waste water during the pre-treatment process (mechanical filter) --> dumped at landfill site or incinerated.	interview with local government, Kirk-Othmer Encyclopedia
		1	Nickel screens	End-of-life rotary screens are sold by screen engraving company to scrap companiesd for recycling. Nickel recycling is done by melting the Nickel. No or less process chemicals are used.	information from external engraving company, Kirk-Othmer Encyclopedia
		1	misprints	Misprints are sold to fabric shop, they sell it to people who want to make their own clothing. **What do they do with fabric that is not sold?**	textile printing company info
		3	general industrial waste	Collected by local government, disposed on landfill facility. No treatment before disposal. **Components general industrial waste textile printing company --> better purposes?**	textile printing company info
5,4	liquid residue generated during recycling / waste treatm. process	2 to 3	sludge	50% of sludge is old non-reusable coloured paste, other 50% is waste process chemicals. Sludge is disposed on landfill facility, owned by local government. Landfill site of commercial waste treatment company better quality? No treatment before disposal. Sludge is stored in plastic cans (re-used cans supplied chemicals). Leakage possible?	textile printing company info
		1 to 2	effluent	**See requirements waste water of local government?**	interview with local government, Kirk-Othmer Encyclopedia
		0	Nickel screens	End-of-life rotary screens are sold by screen engraving company to scrap companies for recycling. Nickel recycling is done by melting the Nickel. No or less process chemicals are used.	information from external engraving company, Kirk-Othmer Encyclopedia
		0	misprints	Misprints are sold to a fabric shop, they sell it to people who want to make their own clothing. No liquid residue is generated by selling misprints.	textile printing company info
		0 to 1	general industrial waste	Collected by local government, disposed on landfill facility. No treatment before disposal. **Components general industrial waste textile printing company --> better purposes?**	textile printing company info
5,5	gas residue generated during recycling / waste treatm. process	1 to 2	sludge	50% of sludge is old non-reusable coloured paste, other 50% is waste process chemicals. Sludge is disposed on landfill facility, owned by local government. Landfill site of commercial waste treatment company better quality? No treatment before disposal. Sludge is stored in plastic cans (re-used cans supplied chemicals).	textile printing company info
		2?	effluent	H2 and N2 emissions are generated during aeration process. Methane emissions (used for heating purposes), CO2 emissions and H2S emissions (limited amount) are generated during digestion process.	interview with local government, Kirk-Othmer Encyclopedia
		0	Nickel screens	End-of-life rotary screens are sold by screen engraving company to scrap companies for recycling. Nickel recycling is done by melting the Nickel. No or less process chemicals are used.	information from external engraving company, Kirk-Othmer Encyclopedia

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies					
		0	misprints	Misprints are sold to a fabric shop, they sell it to people who want to make their own clothing. No gaseous residue is generated by selling misprints.	textile printing company info
		0	general industrial waste	Collected by local government, disposed on landfill facility. No treatment before disposal. **Components general industrial waste textile printing company --> better purposes?**	textile printing company info

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To assess the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

APPLICATION OF THE EUROPEAN UNION ECO-LABELLING REQUIREMENTS AT THE TEXTILE PRINTING COMPANY

A1. Ecological criteria: textile fibers

This section is related to the chemical composition and manufacturing process of various textile fibers, namely:
1. acrylic
2. cotton
3. elastane
4. flax and other bast fibers (incl. hemp, jute and ramie)
5. greasy wool and other keratin fibers (incl. wool from sheep, camel, alpaca, goat)
6. man-made cellulose fibers (incl. viscose, lyocell, acetate, cupro, triacetate)
7. polyamide
8. polyester
9. polypropylene

This whole section is not applicable to the textile printing company since the company has no influence on the type of fiber that their clients use.

A2. Ecological criteria: processes and chemicals

10. *carding and spinning oils, waxes, finishes, lubricants and sizeing applied to fibers and yarns*

These requirements are not applicable to a printer of textiles.

11. TCP and PCP

Tetrachlorophenol (TCP) and pantachlorophenol (PCP), including their salts and esters, are not allowed to be used and could be applicable to a printer of textiles. However, they are not applicable to the textile printing company since the company does not use TCP and PCP.

12. Stripping and depigmentation

Heavy metals salts (except of iron) or formaldehyde shall not be used for stripping and depigmentation.

Screenwash is used as a cleaning agent for the rotary screens after printing. The composition of this chemical is not known. The MSDS shows that the screenwash is highly flammable and harmful. The stripping of the rotary screens is done externally by a company called Omni Screens. Insight is needed into the chemical composition of the screenwash and the stripping agent.

Acetone is used as a cleaning agent for the flatbed screens after printing. A combination of ammonia 25%, sodium hydroxide and calcium hypochloride is used to strip the flatbed screens. None of these chemicals contain heavy metals or formaldehyde.

13. Weighting

Compounds of cerium are not allowed to be used in the weighting of yarn and fabrics. These requirements are not applicable to the textile printing company.

14. Detergents, fabric softeners and complexing agents

Alkylphenolethoxylates (APEOs), bis(hydrogenated tallow alkyl dimethyl ammonium chloride (DTDMAC), distearyl dimethyl ammonium chloride (DSDMAC), di(hardened tallow) dimethyl ammonium chloride (DHTDMAC) and ethylene diamine tetra acetate (EDTA) are not allowed to be used.

95% by weight of the detergents, fabric softeners and complexing agents used shall be sufficiently degradable or eliminable in waste water treatment plants.

The textile printing company does not use detergents, fabric softeners and complexing agents so the above mentioned requirements are not applicable to them.

15. Bleaching agents

AOX emissions in the mixed bleaching effluent shall be less than 40 mg Cl/kg. The textile printing company does not have bleaching processes, so these requirements are not applicable to the company.

16. Impurities in dyes

Dyes are not allowed to have ionic impurities. Maximum concentrations are given for Ar, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Sn and Zn. These requirements can be applicable to a printer of textiles. The textile printing company uses pigments instead of dyes, so this section is not applicable to the case-study company.

17. Impurities in pigments.

Maximum allowed concentration of metal components (As, Cd, Cr, Hg, Pb, Sb and Zn) in pigments are given. Oro Pallido pasta is used by Textile Printers. This gold pigment contains Zinc and Copper. It is the question if the concentration of Zinc and Copper in the Oro Pallido pasta is within the given limits. The textile printing company uses no other pigments with metals listed in these requirements.

18. Chrome mordant dyeing / 19. Metal complex dyes / 20. Azo dyes / 21. Dyes that are carcinogenic, mutagenic or toxic to reproduction / 22. potentially sensitising dyes

Section 18 describe that chrome mordant dying shall only be used for wools and ther keratin fibers, and only if low-chrome dyeing is applied. Section 19 summarises the requirements regarding to metal complex dyes and waste water treatment. A list of prohibited aromatic amines for Azo dyes is given in section 20. Section 21 mentions that certain carcinogenic, mutagenic or toxic dyes are not allowed to be used. In section 22 potentially sensitising dyes are summarised which are prohibited to be used.

The requirements in these sections can be applicable to a printer of textiles. The case-study company uses pigments instead of dyes, so these sections are not applicable to the company.

23. Halogenated carriers

Halogenated carriers are not allowed to be used. The textile printing company does not use halogenated carriers so this requirement is not applicable to the company.

24. Printing

This section is obviously related to a printer of textiles and contains limits for volatile organic compounds in print pastes. The maximum value of VOC compounds in the print paste is 5%.

The print pastes used at the flatbed plant uses print pastes based on white spirits, the rotary plant uses water based print pastes. The print pastes used at the flatbed plant do not meet the VOC-requirements of the EU eco-labelling scheme, A thickener and a specific ready-made print paste (used at rotary and flatbed plant) contain VOC-compounds.

The following process chemicals are not print paste components, but do have VOC-compounds:
- glue to stick mesh on screens, only used at flatbed plant
- glue hardener, added to Estalan NDW, only used at flatbed plant
- dissolving liquid to remove metal ring from rotary screen after printing, only used at flatbed plant)
- emulsion hardener, only used at flatbed plant

25. Formaldehyde

Formaldehyde is not allowed to end up in the final fabric product. The following process chemicals used by the textile printing company contain formaldehyde:
- pasta component – fixing agent
- ready-made print pasta – white

Pastisol-based printing is also not allowed. This printing process is not applied by the textile printing company.

26. Waste water discharges from wet-processing

The following requirements are set for:
- COD: less than 2.5 gram per kg (2500 mg/liter)
- pH: between 6 and 9
- temperature: less than 40 degrees Celcius

The textile printing company meets the COD, pH and temperature requirements set by the CMC, but would have to reduce further to meet the EU eco-labelling requirements. The results of the sampling done by the local government will give more insight.

27. Flame retardants

These requirements describe that flame retardants which are carcinogenic, may cause heritable genetic damage, are (very) toxic or harmful to aquatic organisms/environment, may impair fertility or may cause harm to the unborn child shall not to be used.

These requirements are not applicable to the textile printing company, since flame retardants are not used by them.

28. Shrink resistant finishes

This section states that halogenated shrink-resist substances or preparation shall only be applied to wool slivers. These requirements are not applicable to the textile printing company since these substances are not used by the company.

A. Fitness for use

29. Dimensional changes during washing and drying

This section describes that dimensional changes are not allowed to exceed 6% (length and width) for knitted products. The case-study company prints on knitted products. The process steps curing and stentering at the textile printer will have influence on the dimensional changes of the printed product. Tests will be needed to determine if the dimensional changes are within the limits.

30. Colour fastness to washing

These requirements describe that the colour fastness to washing shall be at least level 3-4. These requirements are related to the dyeing and printing of fabrics. Tests will be needed to determine if the colour fastness for washing are within the limits.

31. Colour fastness to perspiration (acid, alkaline)

These requirements describe that the colour fastness to perspiration shall be at least level 3-4. These requirements are related to the dyeing and printing of fabrics. Tests will be needed to determine if the colour fastness to perspiration are within the limits.

32. Colour fastness to wet rubbing

These requirements describe that the colour fastness to wet rubbing shall be at least level 2-3. These requirements are related to the dyeing and printing of fabrics. Tests will be needed to determine if the colour fastness to wet rubbing are within the limits.

33. Colour fastness to dry rubbing

These requirements describe that the colour fastness to dry rubbing shall be at least level 4. These requirements are related to the dyeing and printing of fabrics. Tests will be needed to determine if the colour fastness to dry rubbing are within the limits.

34. Colour fastness to light

These requirements describe that the colour fastness to light shall be at least level 5 and are only applicable to fabric intended for furniture, curtains or drapes. For this reason, the requirements in this section are not applicable to the textile printing company.

B. Energy and water use

The case-study company will be requested, on a voluntary basis, to provide detailed information on water and energy use for the rotary and flatbed plant.

The electricity and water use has been monitored by Industrial Symbiosis research project. This data will probably be satisfactory to meet the requirements of the EU eco-labelling scheme, but the monitoring needs to be done on a regular or continuous basis.

In this section an overview is given of the organisations related to and/or specialised in the South African metal finishing industry. Although it was tried to make this overview as complete as possible, it can not be ensured that all specialised / metal finishing related organisations have been included in the following discussion.

National Association of Automobile Component & Allied Manufacturers (NAACAM)

Generally NAACAM provides a forum for the exchange of ideas and results in the formulation of policy decisions with regard to the economy in general and the automobile industry in particular.

NAACAM offers a vast spectrum of services as [NAACAM, 1997]:
- information on matters affecting the motor industry;
- export incentives and potential leads;
- introduction to and contacts with those Government officials with a direct bearing on the motor industry;
- participation in overseas missions and international trade fairs;
- developments regarding the motor industry programme, investment opportunities and business trends;
- advice or guidance regarding the more productive use of the factors of production;
- assistance with regard to technology transfer, small business development aid or where to locate a new factory;
- assistance with the determination of the applicable tariff heading under which to import and what duty levels;
- assistance with the presentation of applications for increased tariff protection and/or the introduction of rebate facilities;
- indication of future expectations to assist with forward planning.

National Association of Automobile Manufacturers South Africa (NAAMSA)

NAAMSA is a source of information about the motor industry in sub-Saharan Africa. After 50 years of being the official body representing new vehicle manufacturers, it is now going through major changes in line with the transformation of the industry. The NAAMSA membership base now includes major importers and distributors of new vehicles as well as local manufacturers and assemblers. Every month NAAMSA releases new vehicle sales figures, consumer trends and general fiscal health. There is a NAAMSA working group or specialist committee tackling each of the major issues facing the industry – ranging from local content to vehicle crime and safety legislation.

Association of Architectural Aluminium Manufacturers (AAAMSA)

AAAMSA is an organisation within South Africa which is committed to the disciplines and standards of quality which surround the manufacture and installation of architectural aluminium products, interior building systems, glass and glazing and associated activities. AAMSA provides a forum for the exchange of expertise and interaction between individuals and organisations to create a competitive advantage for the aluminium industry. AAAMSA communicates to all stakeholders in the architectural aluminium industry and registers the accredited members of AAAMSA who have satisfied the associations requirements of predetermined standards.

Aluminium Federation South Africa (AFSA)

AFSA is a non-profit making organisation, which represents the aluminium industry in South Africa. AFSA's primary objective is to promote the use of aluminium through generic marketing and advertising education and training, dissemination of technical literature, design assistance, seminars, workshops and personal contacts. Membership is open for all corporations, companies and other organisations engaged in Southern Africa. AFSA is divided into a number of associations which represent specific market sector interests, like the engineering, building and recycling sectors. To assist the appropriate choice of aluminium as a practical and cost-effective solution AFSA has produced and is producing a number of handbooks and literature about "product awareness". AFSA also provides technical assistance in design, joining, welding and fabrication.

Motor Industry Training Board (MITB)

The MITB was established in 1989 with representation of the South African Motor Industry Employers Association (SAMIEA), National Union of Metalworkers of South Africa (NUMSA), Motor Industry Employees' Union (MIEU) and the Motor Industry Staff Association (MISA).

The function of the MITB is:
- to provide and co-ordinate training and education for all employees in the motor industry, as prescribed by the Training Board;
- to administer registration of contracts, progress reports, prescribed testing, certification and remuneration;
- to monitor the students' performance, update training material and programmes and identify additional training needs.

The MITB consists of a national office (situated in Randburg, Gauteng) and six Regional Training Committees.

Steel and Engineering Industries Federation of South Africa (SEIFSA)

Employers in the metal and engineering industry established the SEIFSA in 1943. SEIFSA is currently one of the largest employer organisations in South Africa consisting of 41 associations with a total membership of some 2800 companies. Member companies range from small enterprises with fewer than 25 employees to large corporations employing more than 5000 employees. SEIFSA strives to promote the common interest of its members, regardless of their size – 50 percent of its members are small companies employing fewer than 25 workers. SEIFSA employs specialist staff to represent employers' interest on the boards of numerous regulatory and advisory bodies and to the trade unions. SEIFSA also provides members with a range of important and professional back-up services which most companies can not afford individually. Member companies have immediate access to authoritative industrial relations advice concerning company-level disputes over allegations of unfair dismissals and unfair labour practices. SEIFSA provides its members with statistical information, advise and training and regulation information concerning export promotion assistance, taxation, tariffs and import controls.

National Union of Metal Workers (NUMSA)

NUMSA is the largest metalworkers union (and second largest trade union) in South Africa with close to 232,000 members. In 1987 NUMSA was born from a merger of seven unions in the metal industry. NUMSA is also affiliated to the Congress of South African Trade Unions (COSATU) – the largest trade union federation in South Africa. NUMSA's key activity is collective bargaining with employers. However, there are other key areas of activity such as training and health, safety and environment. The structures of NUMSA are all based on the need for strong, democratic workers' control of the union. NUMSA has members in many sectors of the metal, motor and rubber industries. To co-ordinate organising and negotiations in these sectors, and to unite workers with different employers in these sectors, NUMSA has two departments: an engineering department and a motor industry department.

Ref no.	Improvement options selected by waste minimisation assessment at the powder coating company	Identified by?	Selected for detailed wm-feasibility study?	Proven feasible?
1.	**Drag-out reduction**			
1.A	Apply longer dwelling time for parts over process bath in order to reduce drag-out.	Literature review	Yes	**(Yes)**
1.B	Install rack over passivation bath to hang jig before moving to drying area in order to reduce drag-out.	Literature review	No	N.A.
2.	**Water use reduction**			
2.A	Install flowmeters in-line to monitor rinse flow rate and water use (raise awareness as to water usage).	Literature review	No	N.A.
2.B	Reduce flowrate in rinse tanks to optimum (co-ordinate actual water use and water use requirements).	Literature review	Yes	No
2.C	Reduce or stop flow rate in rinse tanks during low / non production periods.	Literature review	Yes	Yes
2.D	Install flow restriction and control devices.	Literature review	No	N.A.
3.	**Waste water reduction**			
3.A	Treat wastewater and reuse (closed water system)	Literature review	No	N.A.
4.	**Paint overspray reduction (improved first transfer efficiency)**			
4.A	Optimise distance between parts for painting so that overspray and Faraday effect are reduced.	Brainstorming session	No	N.A.
4.B	Optimise the position of products during spraying in spray booth in order to minimise spraying outside the booths.	Brainstorming session	No	N.A.
4.C	Improve operator skill through a continuous interactive and motivational training programme.	Brainstorming session	Yes	**(Yes)**
4.D	Implement a continuous control programme for ensuring equipment is properly set up at all times.	Brainstorming session	Yes	Yes
4.E	Improve booth design to minimise spraying outside the booths.	Brainstorming session	Yes	Yes
4.F	Renew old paint application equipment over a period of time.	Brainstorming session	Yes	Yes
5.	**Paint use reduction options**			
5.A	Install a continuous feeding device for parts in spray booths to ensure minimum overlap of paint on parts.	Brainstorming session	Yes	Yes
5.B	Change to alternative powder supplier for powder which gives improved m2 painted/kg paint used.	Brainstorming session	No	N.A.
6.	**Other paint waste reduction options**			

Ref no.	Improvement options selected by waste minimisation assessment at the powder coating company	Identified by?	Selected for detailed wm-feasibility study?	Proven feasible?
6.A	Implement continuous maintenance programme for ensuring leaks from all equipment (guns, hopper, connecting pipes and cyclones) are minimised.	Brainstorming session	Yes	(Yes)
6.B	Use vacuum suction instead of compressed air blow-out for cyclone and booth cleaning in order to prevent small particles being emitted to atmosphere.	Brainstorming session	No	N.A.
6.C	Improve cyclone efficiency through modifications in order to minimise paint waste.	Brainstorming session	No	N.A.
6.D	Install filters after cyclone to capture paint dust fines that are not collected.	Brainstorming session	No	N.A.
7.	**Reduce bath contamination from paint dust**			
7.A	Separate paint area from pre-treatment area	Brainstorming session	No	N.A.
7.B	Modify or renew paint booths so that they operate at an underpressure (pressurised paint booths).	Industry expert	No	N.A.
7.C	Install covers over bath over night to prevent paint from settling in bath during night shift (also insulation)	Brainstorming session	No	(No)
8.	**Substitution of chromate conversion chemical**			
8.A	Substitute the chromate conversion chemical with a Chrome-free alternative.	Literature review	Yes	Yes
9.	**Substitution of passivation bath**			
9.A	Substitute the passivation bath with demineralised water.	Supplier	Yes	Yes
10.	**Oil filtration**			
10.A	Install oil filtration equipment for degreaser.	Literature review	No	N.A.
11.	**Record keeping**			
11.A	Maintain improved chemical tracking and record keeping.	Literature review	Yes	Yes

Each of the wastes is given a point value for each criteria. The points are then summed and the wastes with the highest total score are selected as focus area (up to a maximum of 4) [Jänisch, 2000].

QUANTITY

Quantity	Point value
> 100,000 kg or liter per year	5 = very high
25,000 – 100,000 kg or liter per year	4 = high
5,000 – 25,000 kg or liter per year	3 = average
1,000 – 5,000 kg or liter per year	2 = low
0 – 1,000 kg or liter per year	1 = very low
0 kg or liter per year	0 = none

HAZARDOUS NATURE

In assessing the hazardous nature, consideration should be given to the hazardous rating of the substances that make up the waste, as well as to the relative concentration of the hazardous substance. In addition, consideration should be given to the final disposal point of the waste e.g. river versus sewer.

Point system	Hazardous nature
1	very low
2	low
3	medium
4	high
5	very high

ENERGY CONSUMPTION

Quantity – gas	Point value
0 – 10,000 kg per year	1 = low
10,000 – 20,000 kg per year	2 = medium
20,000 – 50,000 kg per year	3 = high
> 50,000 kg per year	4 = very high
Quantity – electricity	**Point value**
0 – 500,000 kWh per year	1 = low
500,000 – 1,000,000 kWh per year	2 = medium
1,000,000 – 1,500,000 kWh per year	3 = high
> 1,500,000 kWh per year	4 = very high
Also kVA	Add 1 point


Raw materials extraction
Raw materials processing
Intermediate product production
Trading / assembling organisations
Transporters
iron ore extraction
iron & steel production
metal products production
assembling org. tools/machinery
forest felling
pulp & paper production
packaging production
trading org. packaging
oil / greases / fuel production
trading org. oil / greases / fuel
sea forwarding company
fossil fuel extraction
petro-chemical production
printing chemicals production
trading org. printing chemicals
synthetic fibre production
cotton growing
cotton scouring and spinning
fabric weaving or knitting
fabric dying and finishing (commission)
CMT's (Cut, Make, Trim)
manufacturers of additional parts (buttons, zips etc.)
Electricity
ESKOM (generator of electricity)
Shareholders
holding company
Government
national government
Industrial Development Programme (financial incentive schemes)
local government for legislation, water, electricity
Water treatment companies (owned by local government)
Support organisations
COSATU (umbrella org.)
SACTWU (employee org.)
South African Qualification Athority (SAQA)
SACTPEA (employer org.)
National Standard Body (NSB) Textile, clothing and footwear
Textile Federation
Standard Generating Body (SGB) Textile, clothing and footwear
management consultant agency
Textile Training Board
screen engraving company
University
community support organisations
TEXTILE PRINTING COMPANY
Design
Local design houses: (forwarding + designing + sampling + quality control)
Transporters
road and air transport company for samples
road transport company for bulk orders
Waste treatment companies
waste water treatment plants (owned by local government)
local government
landfill facility
fabric shop
local plastic collectors
Local clothing manufacturers : (forwarding + design + CMT + knitting)
Local clothing manufacturers: (forwarding + design + CMT)
National clothing manufacturers: (forwarding + design + CMT)
Clothing manufacturers
Clothing retailers
Chains S.A.
Own shops of clothing manufacturers S.A.
Export market
Informal market
product end-users
Maintenance
maintenance company a (machinery)
maintenance company b (machinery)
maintenance company c (electrical)
maintenance company d (plumbing)
maintenance company e (building)
Competitors
local competitors (only printing)
local competitors (fabric manufacturing + CMT + printing)
national competitors (only printing)
national competitors (fabric manufacturing + CMT + printing)
Research project "Industrial Symbiosis View of SMEs"
Dick van Beers / Bas Kothuis
University of Cape Town
Department of Chemical Engineering
Environmental Process Engineering Group
Rondebosch 7700
Cape Town, South Africa
Tel. (++27) (0)21 650 4035
UPDATE 4-1-2000
flow intensity
material flow [kg/tonnes per year]
finance flow [Rands per year]
information flow [personal contact]
very high
> 100,000
> 1,000,000
daily
high
10,000 to 100,000
100,000 to 1,000,000
weekly
medium
1,000 to 10,000
10,000 to 100,000
monthly
low
0 to 1,000
0 to 10,000
yearly
FLOW INTENSITY
very high =
high =
medium =
low =
material flow =
finance flow =
information flow =

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UPDATE 8-2-2000

flow intensity	material flow [kg/liters/prod. per year]	finance flow [Rands per week]	information flow [personal contact]
very high	> 100,000	> 1,000,000	daily
high	10,000 to 100,000	100,000 to 1,000,000	weekly
medium	1,000 to 10,000	10,000 to 100,000	monthly
low	0 to 1,000	0 to 10,000	yearly

COSTS

Costs	Point value
> R100,000 per year	5 = very high
R25,000 – R100,000 per year	4 = high
R5,000 – R25,000 per year	3 = average
R1,000 – R5,000 per year	2 = low
R0 – R1,000 per year	1 = very low
R0 per year	0 = none

WASTE MINIMISATION POTENTIAL

Does the assessment team believe that there is potential for waste minimisation (based on a good knowledge of WM-options for the process)?	High potential = 3
	Low potential = 2
	No idea = 1

OTHER

This criteria takes into account factors not addressed by the previous evaluation criteria.

Compliance with present or known future regulations or charges	Yes = 0 No = 1
Potential environmental liability?	Yes = 0 No = 1
Safety hazards to employees and surrounding areas?	Yes = 0 No = 1
Existing reuse / recycle?	Yes = -1 No = 0

Ref.no.	NETWORK BRAINSTORMING SESSION – RESULTS POWDER COATING COMPANY	
1.	**Energy**	**Comments**
1.1	Can waste heat be utilised, exchanged between processes, exchanged between companies?	Yes, hot air from oven can perhaps be used to heat up degreasing, etching and passivation baths?
1.2	Can energy costs be directly allocated to budgets / process steps to encourage better control?	No, energy costs can't be allocated to each process steps. Need for installation of energy meters on all equipment/machines?
1.3	Is there scope for better energy housekeeping? For example: - Can processes or buildings be insulated more effectively? - Can more energy-efficient lighting be installed? - Are buildings maximising use of passive heating and cooling?	Yes, better insulation of tanks, ovens and building is possible.
1.4	Can raw materials be produced or dried with less or renewable energy?	Perhaps can solar energy be used to heat up degreasing, etching and passivation bath.
1.5	Can processes be integrated to create energy savings?	Yes, use hot air from oven to heat up degreasing, etching and passivation bath.
1.6	Is the drying process managed optimally? Can products be manufactured with less energy? A thermostat or hygrostat controlled process is more efficient than a time controlled process.	Between pre-treatment and powder coating only air drying takes place, forced drying will give better quality. This is more energy intensive.
1.7	Can the process times and temperatures be adjusted more efficiently?	The aluminium to be cured should be 200 degrees Celcius for 10 minutes. Temperature of aluminium is already be measured, but is only visible on graph after product is taken out of the oven. Installation of infra-red meter would make it possible to determine optimum process time of product in oven. Oven time is now determined based on experience.
1.8	Can more use be made of renewable energy in production or processing?	See point 1.6.
2.	**Environmental management**	**Comments**
2.1	Reduce quantities of raw materials to levels where materials will be used up just as new materials are arriving (Just-In-Time production).	Stock of process chemicals is already kept as low as possible. It's only possible to order coloured powder in 20 kg bags. White powder can be bought in small quantities. No market to sell small quantities of powder in South Africa. There are only a few powder coaters of architectural aluminium in South Africa.
2.2	Do you use all the samples you receive from chemical suppliers (no-used samples are hazardous waste)?	N.A.
2.3	Can expired products be returned to its supplier?	No, but process chemicals almost never expire at Powder coating company. Powders can be used until far after expiry date, this is discussed with the powder supplier. Normally the powders are expired after 12 months.
2.4	Do all the suppliers send the Material Safety Data Sheets for all the (new) chemicals that they supply?	Yes, but only on request.
2.5	Can the product or service be combined with others to reduce overall material and energy intensity?	This already happens → oven is filled completely with products before curing process starts.
2.6	Can customers be informed or educated about ways of extending product durability?	Yes, powder coating company just sent a document to all their clients in which it is stated how the powder coated aluminium should be maintained to extend durability of product.

Ref.no.	NETWORK BRAINSTORMING SESSION – RESULTS POWDER COATING COMPANY	
2.7	Can "green" ideas be exchanged between your company, network partners, and other companies in the same industry?	Yes, powder coating company could tell their competitors the advantages of having a Cr-fee pre-treatment process. But this unlikely going to happen due to high competition and contact between Four and competitors is limited.
2.8	Can your industry organisation or other knowledge providing institution provide you with information concerning "green" clients / markets (in present and in the future)?	Aluminium Federation of South Africa focuses on quality standards rather than environmental issues. There are about 100 powder coaters in the Cape Town area of which only 5 are powder coaters of aluminium. This is why the services of AFSA are not directly linked to production process of Powder coating company.
2.9	Can changes in the environmental legislation be expected which require changes in the production process?	YES!! This is the main reason for Powder coating company to join the Industrial Symbiosis project → waste minimisation assessment.
2.10	Can funding be obtained from the government (local, regional, national funding programmes) to improve the economic / environmental performance of your company?	Powder coating company is familiar with the Cleaner Production Scheme but this scheme is not useful to Powder coating company.
3.	**Inspection / maintenance**	**Comments**
3.1	Can yields be increased by better maintenance, control, or other means? For example: - are pumps, valves, and pipes inspected regularly to minimise leaks? - Could better maintenance of boilers and other equipment improve energy efficiency? Are the burners of the boilers and dryers cleaned regularly? Are they the right size? - Are all hot and cold transportation pipes isolated? - Are equipment and vehicles properly maintained so that emissions are kept to a minimum?	Yes, this is one of the selected options generated by the waste minimisation assessment.
3.2	Are supplied products/raw materials inspected as they arrive in your company? Identify why the quality criteria are not met.	Powder coating company checks the incoming products on quantity and size → for the invoice. All incoming products are not checked on quality, this is the responsibility of the client. It is not feasible, time-wise, to check every incoming product.
3.3	Can material use be minimised by improved mechanical design / machinery / equipment?	Yes: - improve spray booth design - improve powder application equipment - improve cyclone
4.	**Packaging**	**Comments**
4.1	Can packaging be eliminated or reduced by: - integrating transportation packaging design with product packaging - making products of smaller size, or a different shape - using the packaging more than one time	Yes, perhaps by designing a reusable packaging system to pack incoming and outgoing products. Product is now wrapped in paper and plastic tape.
4.2	Can the environmental effect of the packaging be reduced?	Environmental effect of packaging (plastic and tape) is already quite low. The environmental effect will be reduced by using less or recycling the packaging.
4.3	Can product packaging be made more recyclable?	Product packaging is already recyclable, but it is disposed as domestic waste. Is it technically and economically feasible to recycle paper packaging?
4.4	Can used packaging be returned to its supplier for recycling and reuse?	Empty chemical cans are returned to supplier, or sold to plastic recycler or reused internally.

Ref.no.	NETWORK BRAINSTORMING SESSION – RESULTS POWDER COATING COMPANY	
5.	**Process optimisation**	**Comments**
5.1	Can supplied products and raw materials be produced or processed in less materially intense ways?	Yes: - improve spray booth design - improve powder application equipment - improve cyclone
5.2	Can water consumption be reduced?	Yes, this is one of the focus areas of the waste minimisation assessment.
5.3	Can harmful (toxic) substances be eliminated from production processes and remaining harmful substances be recycled or incinerated?	Addressed during waste minimisation assessment.
5.4	Can more use be made of resources that are certified as being sustainably produced?	N.A.
5.5	If the following liquids are used in any manufacturing process, is their use minimised, and have substitutes been investigated? - solvents or oils - organic species of concern - acids - nutrients	No solvents and oils are used by powder coating company. The following acids are used: - Nitric acid - Chromic acids This issue is addressed during waste minimisation assessment.
5.6	Do some of the network partners have special requirements which have no effect on the quality of purpose of the products or services, but which have a negative economic/environmental effect on your production process?	Some clients have special requirements regarding the product packaging → plastic instead of paper.
6.	**Product design**	**Comments**
6.1	Can products/services be redesigned/adjusted, so that - less waste is created in later stages - less use of materials and energy inputs is made, also during the user-phase - renewable and abundant materials are used instead of scarce and non-renewable ones - more use is made of recyclable materials/components (material point of view)	No, managing director is not aware of possibilities regarding this point. But perhaps it is worth investigating?
6.2	Can products/services be redesigned/adjusted, so that - end-of-life products can be disassembled easily - end-of-life products are easier to dispose off (end-of-life point of view)	End-of-life product (architectural aluminium with glass) can be disassembled and recycled easily. Scrap price of aluminium is quite high (6 Rand per kg) so there is a great incentive to recycle aluminium. Powder on end-of-life product will be incinerated during the recycling process of aluminium.
6.3	Can products/services be redesigned/adjusted, so that - products/components are made modular to allow easy upgrading - longevity of the product or the production equipment/tools is improved - distribution and logistics is made easier (service point of view)	Yes, powder coating company just sent a document to all their clients in which it is stated how the powder coated aluminium should be maintained to extend durability of product. See point 2.6.
6.4	Can the product (components) be marked so that the recyclability is made easier (eco-labelling)?	N.A. Aluminium products are easily to recognise. See point 6.2.
6.5	Can the properties of the product be accentuated or developed for greater customer value?	Replacing the chromic acid by demineralised water in the passivation process will improve the quality of the end-product.

Ref.no.	NETWORK BRAINSTORMING SESSION – RESULTS POWDER COATING COMPANY	
6.6	What services are customers really getting from your product? Can this be provided more effectively or in complete different ways?	N.A.
6.7	What services will customers need in the future? Can you design new or develop existing products to meet them?	What services and products customers need in the future depends on the availability of technology. Powder coating company is not a pioneer. Based on request of clients, powder coating company will try to meet the new demands together with the help of suppliers.
6.8	Is your product providing other services as well as the most obvious one? Can these be accentuated or enhanced? Can the product or service be integrated or synchronised with others to provide multifunctionality?	???
7.	**Transport**	**Comments**
7.1	Can transport be reduced or greater use be made of energy-efficient transport such as rail?	Most of the chemicals and powders come from Johannesburg, but are supplied via an agent in Cape Town. Transport by road or rail?
7.2	Can products be transported or distributed by alternative means to enhance customer value and reduce environmental impacts?	???
7.3	Can production be localised to both enhance service and reduce transport needs?	No.
8.	**Wastes**	**Comments**
8.1	Can waste disposal costs be reduced by any way (give in waste more separate, change concentration, other size drums / cans, combine transport with other companies in the region)?	Combine transport of (hazardous) wast might be possible. Disposal costs are no major costs to Powder coating company → no priority.
8.2	Are there any opportunities to recycle, remanufacture or re-use wastes, in- and outside company (participate in waste exchange schemes)?	Perhaps, assess possibility to participate in waste exchange program. Give proposal for a CMC Industrial Waste Exchange project to managing director.
8.3	Use processing methods which generate treatable or recyclable waste on-site. Track the non-recyclable waste streams in the company and ask suppliers for alternative products.	Track the non-recycle waste streams of powder coating company and ask suppliers for alternative products. See network assessment.
8.4	Can products, which don't meet the quality standards, be reused, remanufactured, or recycled?	Yes. The 1st option is the overcoat the aluminium again. The 2nd option is to strip the powder coated aluminium with sulphuric acid, but this has major negative environmental effects. The 3rd option is to blast the powder coated aluminium with plastic blasting material which is very expensive. Powder coating company considers to buy own blasting machine (R 50.000). Powder coating company does not have enough waste products to make this investment economically feasible → value of waste products of Powder coating company is about R 10,000 per year.
8.5	Can end-of-life products be reused, remanufactured, recycled, or incinerated?	Yes, see point 6.2.
8.6	Can customer's disposal problems be eliminated by providing a take-back service?	N.A.
8.7	Can the wastewater treatment plant treat the wastewater of the related process steps (more efficient)?	There is no wastewater treatment plant yet, but the installation of treatment plant is investigated for waste minimisation purposes.

Ref.no.	**NETWORK BRAINSTORMING SESSION – RESULTS POWDER COATING COMPANY**	
8.8	Can support organisations provide the needed environmental training to employees who deal with hazardous chemicals and wastes? The key to any waste minimisation effort is employee participation. Training and educational programmes can inform employees about waste minimisation and its benefits.	Aluminium Federation of South Africa only provides training related to the production of aluminium (product, not to powder coating of aluminium products.

NETWORK IMPACT MATRIX

UPDATE: 19 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 POWDER COATED ALUMINIUM

environmental concerns		rating*	selected products / materials**	environmental stressors	explanation why rating was chosen	reference
Pre-manufacturing: raw material extraction/processing, intermediate product production, assembling, trading						
1,1	material choice for products used in pre-manufacturing processes	1	paint stripper	NaOH. Highly alkaline material containing chelates, water dispersible solvents and surfactants	Salt (NaCl) is used as raw material for the manufacturing of sodiumhydroxide (NaOH). Petroleum, crude oil or coal is used for the manufacturing of surfactants and chelates. **Investigate the stripping of waste products with a mechanical process (blasting machine) instead of using a chemical process.**	Interview with UCT supervisor.
		3	wetting agent in degreaser	sodium sulphonate in water	The product is made from a petrochemical feedstock to produce the alkane or alkylbenzene which is then reacted with SO3 derived from **burning sulphur --> possible environmental problems here!**	Interview with UCT supervisor.
		3	degreasing chemical	sodium sulphonate	idem sodium sulphonate - wetting agent degreaser.	Interview with UCT supervisor.
		1	etching chemical	sodiumhydroxide (NaOH)	idem NaOH - paint stripper. The etching of Aluminium with NaOH causes smut (?) which have to be removed by nitric acid solution. **Is etching solution available which does not form smut on aluminium surface during etching?**	Interview with UCT supervisor.
		2-3	desmutting chemical	nitric acid (HNO3)	Ammonia, gas (or coal?) and water are used as raw materials for the manufacturing of nitric acid. MEA (?) or other solution is used to remove CO2 during manufacturing process. Catalysts are also used.	Kirk-Othmer: nitric acid. Interview with UCT supervisor.
		1	etch batch treatment	sulphuric acid (H2SO4)	Sulphur, water and air are used as raw materials for the manufacturing process of sulphuric acid. Sulphur is abundantly available as waste from crude oil refining and mining.	Interview with Harro von Blottnitz.
1,2	energy use during pre-manufacturing processes	3	paint stripper	NaOH. Highly alkaline material containing chelates, water dispersible solvents and surfactants	The electrolysis of NaCl and the concentration of NaOH are the most energy-intensive processes.	Interview with Harro von Blottnitz.
		2	wetting agent in degreaser	sodium sulphonate in water	Apart from crude oil refining, processes are exothermic.	Interview with UCT supervisor.

environmental concerns		rating*	selected products / materials**	environmental stressors	explanation why rating was chosen	reference
Pre-manufacturing: raw material extraction/processing, intermediate product production, assembling, trading						
1,5	gas residue generated during pre-manufacturing processes	3-4	paint stripper	NaOH. Highly alkaline material containing chelates, water dispersible solvents and surfactants	Cl2 is emitted during the manufacturing of NaOH?	Interview with UCT supervisor.
		3-4	wetting agent in degreaser	sodium sulphonate in water	SO2 and SO3 emission are generated during the manufacturing process of sodium sulphonates. These emissions contribute to acidification.	Interview with UCT supervisor.
		3-4	degreasing chemical	sodium sulphonate	idem sodium sulphonate - wetting agent degreaser.	Interview with UCT supervisor.
		3-4	etching chemical	sodiumhydroxide (NaOH)	idem NaOH - paint stripper.	Interview with UCT supervisor.
		4	desmutting chemical	nitric acid (HNO3)	NO and NO2 emissions are generated during the manufacturing process of nitric acid, these emissions cause smog and are toxic. Most often these emissions are treated by catalytic or non-catalytic de-nox installation.	Kirk-Othmer: nitric acid. Interview with UCT supervisor.
		3-4	etch batch treatment	sulphuric acid (H2SO4)	SO2 and SO3 emissions are generated during the manufacturing process of sulphuric acid. These emissions contribute to acidification.	Interview with UCT supervisor.

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

** selection of products and materials for assessment of the pre-manufacturing phase is based on:
- annual consumption
- annual costs
- influencability

NETWORK IMPACT MATRIX

UPDATE: 19 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 POWDER COATED ALUMINIUM

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME					
2,1	material choice for products used in production process of SME	2-3	stripping (removing the old paint on aluminium jigs)	Inputs: NaOH with solvents. **Are the surfactants and chelates biodegradable? Investigate the stripping of waste products with a mechanical process (blasting machine) instead of using a chemical process.**	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		1	degreasing (remove oils/grease from Al-parts prior to etching)	Inputs: sodium sulphonate, sodium sulphonate, H2O. Sodium sulphonate is not a matter of concern.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		1	etching (remove thin aluminium oxide layer and create a rough surface for easier chromate coating)	Inputs: sodium hydroxide, H2O. Sodium hydroxide is not a matter of concern.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		0	rinsing (remove etching chemicals prior to desmutting)	Two rinsing baths: rinse 3 + rinse 4. Input rinse 3: H2O from rinse 4. Input rinse 4: H2O from rinse 6.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		1-2	desmutting (remove smut formed on Al-surface during etching)	Inputs: nitric acid (HNO3), H2O. Nitric acid is used in a very low concentration	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		0	rinse (remove acid from the work before chromating)	One rinsing bath: rinse 6. Input rinse 6: H2O from rinse 8.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		4	chromate conversion (convert the Al to a corrosion-resistant surface that more easily accepts and bonds to powder coating)	Inputs: H2O, chromic and phosphoric acid, chromic acid and fluorides. **Less hazardous alternatives are available --> Cr-free and Cr(III) alternatives. Alternatives are being investigated for waste minimisation purposes.**	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		0	rinse (remove chromating chemicals before passivation)	One rinsing bath: rinse 8. Input: fresh H2O.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME					
		4	passivation (provide a protective seal for prevention of rust)	Inputs: chromic acid, H_2O. **Less hazardous alternatives are available --> demineralised water. Alternatives are being investigated for waste minimisation purposes.**	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		0	drying (dry pretreated parts prior to painting)	Inputs: pretreated parts.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		2-3	powder coating (coat the aluminium parts with the required paint)	Inputs: powder paints (polyester based), air. Polyester based powder coatings are used due to the needed UV-resistance of architectural aluminium. **All powder coatings manufactured in South Africa still contain TGIC-hardener. Alternatives are available (Beta-hydroxyalkylamide) but are more difficult to apply.**	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor. LCA-report on powder paints [anomymous, 1997]
		0	curing (bake the painted parts in the oven)	Inputs: powder coated parts.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		3	treating of etch bath (precipitate aluminium out of etch bath before disposal into sewer.	Inputs: H_2SO_4. Sulphuric acid is hazardous. **Determine if etch bath can be treated with waste acid instead of buying new sulphuric acid to precipitate aluminium.**	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		1	treating of chromate batch (transform Cr^{6+} into Cr^{3+}, then precipitate Cr^{3+} out of the chromate batch)	Inputs: sodiumthiosulphate (Na_2SO_3), lime (CaOH). Sodiumthiosulphate and calciumhydroxide are not a matter of concern.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
2,2	energy use during production process of SME	0	stripping (removing the old paint on aluminium jigs)	No or little energy is used during the stripping of the aluminium products.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
		2	degreasing (remove oils/grease from Al-parts prior to etching)	The temperature of the degreasing bath has to be between 50 to 60 degrees Celcius. Immersion heaters (electricity) are used to heat up the degreasing bath --> simple but not efficient. **Immersion heaters are not powered down when not in use --> Installation of timer? Can hot air from the ovens or solar energy be used to heat up the baths?** Covers for baths for insulation are not very effective, but sufficient. The tanks are insulated as well.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.

environmental concerns	rating *	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME				
	2	etching (remove thin aluminium oxide layer and create a rough surface for easier chromate coating)	The temperature of the etching bath has to be between 45 to 50 degrees Celcius. Immersion heaters (electricity) are used to heat up the etching bath --> simple but not efficient. **Immersion heaters are not powered down when not in use --> Installation of timer? Can hot air from the ovens or solar energy be used to heat up the baths?** Covers for baths for insulation are not very effective, but sufficient. The tanks are insulated as well.	Waste minimisation pre-assessment report. Interview with managing director, WM-facilitator, UCT supervisor.
	0	rinsing (remove etching chemicals prior to desmutting)	No or little energy is used during this rinsing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	desmutting (remove smut formed on Al-surface during etching)	No or little energy is used during the desmutting step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	rinse (remove acid from the work before chromating)	No or little energy is used during this rinsing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	chromate conversion (convert the Al to a corrosion-resistant surface that more easily accepts and bonds to powder coating)	No or little energy is used during the chromate conversion step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	rinse (remove chromating chemicals before passivation)	No or little energy is used during this rinsing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME					
		2	passivation (provide a protective seal for prevention of rust)	The temperature of the etching bath has to be 60 degrees Celcius. The bath is disposed every week on a Friday --> bath is then warmed up during the weekend. Immersion heaters (electricity) are used to heat up the etching bath --> simple but not efficient. **Immersion heaters are not powered down when not in use --> Installation of timer? Can hot air from the ovens or solar energy be used to heat up the baths?** Covers for baths for insulation are not very effective, but sufficient. The tanks are insulated as well.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		0	drying (dry pretreated parts prior to painting)	No or little energy is used during this drying step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		2	powder coating (coat the aluminium parts with the required paint)	Cyclone pumps are used to rewin the emitted powder. These cyclone pumps are energy intensive and are generated by electricity (4 motors of 1.5 kWh). Cyclone pumps are powered down when not in use --> are used for about 90% of the production time. There are no possibilities for heat exchange.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		4	curing (bake the painted parts in the oven)	The curing step is very energy intensive. Gas is used to heat up the baking ovens. Baking ovens are powered down when not in use. "Heat exchange" is already taken place by hanging parts to dry in area around ovens. **Visiting WM-expert suggested that "pilot light" is too large. Paul Abbott will speak to gas supplier to find out how much gas/money can be saved by installing a small pilot light.**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		0	treating of etch bath (precipitate aluminium out of etch bath before disposal into sewer.	No or little energy is used during the treatment of the etch bath.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		0	treating of chromate batch (transform Cr^{6+} into Cr^{3+}, then precipitate Cr^{3+} out of the chromate batch)	No or little energy is used during the treatment of the chromate bath.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
2,3	solid residue generated during production process of SME	3	stripping (removing the old paint on aluminium jigs)	This is a new process. Waste paints of jigs are disposed as hazardous waste by Waste Tech --> disposed on landfill facility.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.

environmental concerns	rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME				
	0	degreasing (remove oils/grease from Al-parts prior to etching)	No or little solid waste is generated during the degreasing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	etching (remove thin aluminium oxide layer and create a rough surface for easier chromate coating)	No or little solid waste is generated during the etching step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	rinsing (remove etching chemicals prior to desmutting)	No or little solid waste is generated during this rinsing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	1	desmutting (remove smut formed on Al-surface during etching)	No or little solid waste is generated during the desmutting step. Some sludge is generated during the passivation, but this goes into solution.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	rinse (remove acid from the work before chromating)	No or little solid waste is generated during this rinsing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	chromate conversion (convert the Al to a corrosion-resistant surface that more easily accepts and bonds to powder coating)	No or little solid waste is generated during the chromate conversion step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	rinse (remove chromating chemicals before passivation)	No or little solid waste is generated during this rinsing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	passivation (provide a protective seal for prevention of rust)	No or little solid waste is generated during the passivation step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME					
		0	drying (dry pretreated parts prior to painting)	No or little solid waste is generated during the drying step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		3	powder coating (coat the aluminium parts with the required paint)	Spent powder and dust from cyclone is generated during the powder coating step. Spent powder is already reused as much as possible, except for frequent colour changes --> wastes time. **Powder application is inefficient and if that is improved, less paint will go through cyclone pump and efficiency will improve --> waste minisation option.**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		0	curing (bake the painted parts in the oven)	No or little solid waste is generated during the curing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		3-4	treating of etch bath (precipitate aluminium out of etch bath before disposal into sewer.	Sludge (precipitated aluminium) is generated during the treatment of the etch bath, this sludge is disposed by commercial waste treatment company (disposed on landfill site). Chemical composition of sludge is unknown. Total amount of aluminium sludge is about 200 liters per year. Price of aluminium is about 6 Rand per kg. Aluminium sludge is not kept/collected seperately, but together with chrome sludge. **Seperate storage of aluminium and chrome sludges?**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		3-4	treating of chromate batch (transform Cr^{6+} into Cr^{3+}, then precipitate Cr^{3+} out of the chromate batch)	Sludge (precipitated Cr+) is generated during the treatment of the chromate batch, this sludge is disposed by commercial waste treatment company (disposed on landfill site). Chemical composition of sludge is Chromium(III)hydroxide. Total amount of chrome sludge is about 1000 liters per year. Chrome sludge is not kept/collected seperately, but together with aluminium sludge. **Seperate storage of aluminium and chrome sludges?**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
2,4	liquid residue generated during production process of SME	4	stripping (removing the old paint on aluminium jigs)	This process step not included in waste minimisation report because this is a new process. **Spent solution?**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.

environmental concerns	rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME				
	4	degreasing (remove oils/grease from Al-parts prior to etching)	Spent solution and drag-out is generated during the degreasing step. The spent solution is contaminated with oil/greases and is disposed into the sewer together with the desmutting bath (neutralisation) without treatment --> **should for treated for environmental reasons.** Spent solution is disposed about twice a year. **Life-span of etching bath can be extended if oils/greases can be filtered out of the solution. Filter oils/greases out of the spent solution before disposing it into the sewer is not done because this is too expensive --> at the moment disposing into the sewer is free (no one is complaining).**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	3	etching (remove thin aluminium oxide layer and create a rough surface for easier chromate coating)	Spent solution and dragout is generated during the etching step. Etching bath is an expensive bath (process chemicals). This spent solution is treated before disposing it into the sewer (see etch bath treatment). **Reason for disposing etch bath is the aluminium from the products which go into solution during the etching process. Can this aluminium be removed through precipitation in order to extend life-span of etching bath?** Sludge is also building up in the etching bath.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	2	rinsing (remove etching chemicals prior to desmutting)	Wastewater and dragout is generated during this rinsing step. The wastewater goes into the sewer without treatment. **WM-facilitator is looking into closed-loop water treatment system.**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	3	desmutting (remove smut formed on Al-surface during etching)	Spent solution and drag-out is generated during the desmutting step --> 6% concentration nitric acid. Desmutting bath is cheap bath (600 Rand of process chemicals). Spent solution is disposed into the sewer together with the degreasing bath (neutralisation) without treatment --> every 1 or 2 years.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	2	rinse (remove acid from the work before chromating)	Wastewater and drag-out is generated during this rinsing step. The wastewater goes into the sewer without treatment. At the moment effluent water is within requirements. Wastewater can be internally reused but is very expensive. **WM-facilitator is looking into closed-loop water treatment system.**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.

environmental concerns	rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME				
	4	chromate conversion (convert the Al to a corrosion-resistant surface that more easily accepts and bonds to powder coating)	Spent solution and drag-out is generated during the chromate step. This spent solution is treated before disposing it into the sewer (see chromate bath treatment) --> every year on advise of chemical supplier. **WM-facilitator is assessing the possibility to change to Cr-free or Cr(III) chemicals.**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	2	rinse (remove chromating chemicals before passivation)	Wastewater and drag-out is generated during this rinsing step. The wastewater is tapped into the rinsing bath after desmutting. **WM-facilitator is looking into closed-loop water treatment system.**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	3-4	passivation (provide a protective seal for prevention of rust)	Spent solution and drag-out is generated during the passivation step. Supplier of passivation bath chemicals says that bath has to be disposed once a week for quality reasons. **The spent solution goes into the sewer without treatment --> low concentration of Cr6+! WM-facilitator is assessing the possibility to change to demineralised water (better for environment).**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	1	drying (dry pretreated parts prior to painting)	Drips (chromic acid and water) fall onto the floor during the drying step. These drips evaporate because of the high temperature in the oven.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	powder coating (coat the aluminium parts with the required paint)	No or little liquid waste is generated during the powder of aluminium.	Waste minimusation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	curing (bake the painted parts in the oven)	No or little liquid waste is generated during the curing of the powder coated product.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	2-3	treating of etch bath (precipitate aluminium out of etch bath before disposal into sewer.	Clarified spent solution is generated during the treatment of the etch batch. This treated spent solution is disposed into the sewer every year. Reason for disposal is that the treated solution still contains aluminium. **If the aluminium could be filtered out, then clarified etch bath could be reused --> cost effective?**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	2	treating of chromate batch (transform Cr6+ into Cr3+, then precipitate Cr3+ out of the chromate batch)	Clarified spent solution is generated during the treatment of the chromate batch. This treated spent solution (almost clear water) is disposed into the sewer. The chromate bath is renewed every year. Clarified spent solution can't be reused internally due to Cr(III) instead of Cr(VI).	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME					
2,5	gas residue generated during production process of SME	2-3	stripping (removing the old paint on aluminium jigs)	Sodium hydroxide is included in the USEPA list of air contaminants. Sodium hydroxide is not a matter of concern for powder coating company --> only health issue, and hazardous in large amounts and high concentrations.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		0	degreasing (remove oils/grease from Al-parts prior to etching)	Water evaporates from the degreasing bath.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		2-3	etching (remove thin aluminium oxide layer and create a rough surface for easier chromate coating)	Sodium hydroxide is included in the USEPA list of air contaminants.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		0	rinsing (remove etching chemicals prior to desmutting)	No or little gaseous emissions are generated during this rinsing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		0	desmutting (remove smut formed on Al-surface during etching)	No or little gaseous emissions are generated during the desmutting step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		0	rinse (remove acid from the work before chromating)	No or little gaseous emissions are generated during this rinsing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		2	chromate conversion (convert the Al to a corrosion-resistant surface that more easily accepts and bonds to powder coating)	Water evaporates from the chromate bath. Chromc acid, phosphoric acid and fluorides are included in the USEPA list for air contaminants --> concentration is low enough not to be a problem with Cr-mist fumes.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
		0	rinse (remove chromating chemicals before passivation)	No or little gaseous emissions are generated during this rinsing step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.

environmental concerns	rating*	subcategory	explanation why rating was chosen	reference
Product manufacturing by SME				
	2	passivation (provide a protective seal for prevention of rust)	Water evaporates from the passivation bath. Chromic acid is included in the USEPA list for air contaminants --> very low concentration, this is not a problem.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	0	drying (dry pretreated parts prior to painting)	A limited amount of water (and chromic acid?) will evaporate during the drying step.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	3	powder coating (coat the aluminium parts with the required paint)	Initial calculations estimate that about 25% of the powder is lost. The cyclone has an efficiency of 90% (to recycle the emitted powders). **WM-facilitator is assessing the possibilities to improve the application equipment, method and style through continuous maintenance, control and training.**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	2	curing (bake the painted parts in the oven)	Gas is used to heat up the oven for the curing step. Products are put into the oven only when the oven has achieved the correct temperature. **Temperature in oven drops significant (about 50 degrees) when doors of oven are opened to put the products into the oven --> modification of oven/process to prevent loss of heat? Better insulation of oven possible?**	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	2-3	treating of etch bath (precipitate aluminium out of etch bath before disposal into sewer.	SO3 emissions are generated by sulphuric acids, only hazardous in high concentrations. SO3 emissions cause acidification and smog.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.
	2-3	treating of chromate batch (transform Cr6+ into Cr3+, then precipitate Cr3+ out of the chromate batch)	Calcium hydroxide is included in the USEPA list for air contaminants. Calcium hydroxide is not a matter of concern for powder coating company --> only health issue, and only hazardous in large amounts and high concentrations.	Waste minimisation pre-assessment report. Interview with managing director, WM-student, UCT supervisor.

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

NETWORK IMPACT MATRIX

UPDATE: 19 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 POWDER COATED ALUMINIUM

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product packaging and transport (to and from SME)					
3,1	material choice for packaging and transport	4	supplied chemicals	Liquid process chemicals are supplied in plastic cans. Solid process chemicals are supplied in plastic bags. **Chemical composition of cans and plastic bags (hazardous components, recyclable, diversity)?**	Interview managing director, WM facilitator, UCT supervisor.
		2	product (aluminium parts)	Incoming (to be powder coated) and outgoing (powder coated) product is wrapped in paper and plastic tape. Two employees of powder coating company are 80% of their time busy with wrapping/packing outgoing powder coated products --> must be done well, otherwise product will get damaged during transport. **Design reusable packaging system to pack incoming AND outgoing products** --> will save powder coating company money on packaging. Cost of packaging are about R2000,- per month. Efficiency improvement of packaging would speed up the production process of powder coating company as well.	Interview managing director, WM facilitator, UCT supervisor.
3,2	energy use during packaging processes and transport	2	supplied chemicals	Suppliers are responsible for transport of supplied chemicals to powder coating company. **Improve transport efficiency / intensity?**	Interview managing director, WM facilitator, UCT supervisor.
		2	product (aluminium parts)	Collection and delivery of incoming and outgoing product is done by powder coating company. If the order is very urgent, collection is sometimes done by the clients (normally the small companies). Powder coating company has two transport vehicles. **Improve transport efficiency / intensity?**	Interview managing director, WM facilitator, UCT supervisor.
3,3	solid residue generated during packaging processes and transport	3	supplied chemicals	Empty chemical cans are sent back to suppliers (deposit of R40 per can, about 15 cans per month), sold to a plastic recycler (R0.40 per can, about 10 cans per month) or reused internally. **Plastic bags are used to pack solid hazardous chemicals, these bags are disposed as non-hazardous industrial waste (ends up on landfill site).**	Interview managing director, WM facilitator, UCT supervisor.
		2-3	product (aluminium parts)	Waste paper and plastic tape is disposed as non-hazardous industrial waste (ends up on landfill site).	Interview managing director, WM facilitator, UCT supervisor.

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product packaging and transport (to and from SME)					
3,4	liquid residue generated during packaging processes and transport	3	supplied chemicals	Contaminated chemical cans are washed out by the supplier (if packaging is taken back by supplier) or by "plastic can collector" --> **do the contaminations of cans (high concentrations of hazardous chemicals!!) end up in the sewer without any treatment?** Supplier will have sufficient equipment/treatment methods to clean or refill chemical cans, The collector of plastic can won't have these facilities. **Can't supplier take back all chemical cans? --> not cost effective for supplier**	Interview managing director, WM-facilitator, UCT supervisor.
		0	product (aluminium parts)	No or little liquid residue is generated during (un)packing and transporting the product.	Interview managing director, WM-facitator, UCT supervisor.
3,5	gas residue generated during packaging processes and transport	3?	supplied chemicals	Gas emissions are generated during transport by ship, plane (long distance) and truck (short distance). Transport by ship relatively clean compared to transport by air. **Toxicity of contaminated empty cans?**	Interview managing director, WM-facitator, UCT supervisor.
		2-3	product (aluminium parts)	No or little gaseous residue is generated during (un)packing the product. Diesel emissions are generated during transport. Transport of product is done by transport vehicles of powder coating company.	Interview managing director, WM-facilitator, UCT supervisor.

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

NETWORK IMPACT MATRIX

UPDATE: 19 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 POWDER COATED ALUMINIUM

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product handling by first, second and third tier clients					
4,1	material choice for products supporting handling / using phase	2	*clients level 1:* aluminium product manufacturers / manufacturers of office partisons / manufacturers of louvres and blinds etc.	**Additional manufacturing or treatment of powder coated product (toxic, scarce, recyclable, material diversity) --> improve product design? Possibilities for applying eco-labelling scheme for powder coated products? Influence of SABS standards on environmental impact in network of powder coating company?**	Interview managing director, WM-facilitator
		2	*clients level 2:* financial institutions / property developers + building contractors / retailers	**Additional manufacturing or treatment of powder coated product (toxic, scarce, recyclable, material diversity) --> improve product design? Possibilities for applying eco-labelling scheme for powder coated products? Influence of SABS standards on environmental impact in network of powder coating company?**	Interview managing director, WM-facilitator
		2	*clients level 3:* consumers	**Additional manufacturing or treatment of powder coated product (toxic, scarce, recyclable, material diversity) --> improve product design? Possibilities for applying eco-labelling scheme for powder coated products? Influence of SABS standards on environmental impact in network of powder coating company?**	Interview managing director, WM-facilitator
4,2	energy use during handling / using product	2?	*clients level 1:* aluminium product manufacturers / manufacturers of office partisons / manufacturers of louvres and blinds etc.	**Additional manufacturing or treatment of powder coated product (energy intensity) --> improve product design? Transport efficiency and effectivety?**	Interview managing director, WM-facilitator
		2?	*clients level 2:* financial institutions / property developers + building contractors / retailers	**Additional manufacturing or treatment of powder coated product (energy intensity) --> improve product design? Transport efficiency and effectivety?**	Interview managing director, WM-facilitator
		2?	*clients level 3:* consumers	**Additional manufacturing or treatment of powder coated product (energy intensity) --> improve product design? Transport efficiency and effectivety?**	Interview managing director, WM-facilitator

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product handling by first, second and third tier clients					
4,3	solid residue generated during handling / using product	2-3	*clients level 1:* aluminium product manufacturers / manufacturers of office partisons / manufacturers of louvres and blinds etc.	**Additional manufacturing or treatment of powder coated product --> improve product design? Packaging efficiency and effectivety? What is done with product after use? What is impact of product after disposal?**	Interview managing director, WM-facilitator
		2-3	*clients level 2:* financial institutions / property developers + building contractors / retailers	**Additional manufacturing or treatment of powder coated product --> improve product design? Packaging efficiency and effectivety? What is done with product after use? What is impact of product after disposal?**	Interview managing director, WM-facilitator
		2-3	*clients level 3:* consumers	**Additional manufacturing or treatment of powder coated product --> improve product design? Packaging efficiency and effectivety? What is done with product after use? What is impact of product after disposal?**	Interview managing director, WM-facilitator
4,4	liquid residue generated during handling / using product	1	*clients level 1:* aluminium product manufacturers / manufacturers of office partisons / manufacturers of louvres and blinds etc.	**Additional manufacturing or treatment of powder coated product --> improve product design?**	Interview managing director, WM-facilitator
		1	*clients level 2:* financial institutions / property developers + building contractors / retailers	**Additional manufacturing or treatment of powder coated product --> improve product design?**	Interview managing director, WM-facilitator
		1	*clients level 3:* consumers	**Additional manufacturing or treatment of powder coated product --> improve product design?**	Interview managing director, WM-facilitator
4,5	gas residue generated during handling / using product	2-3	*clients level 1:* aluminium product manufacturers / manufacturers of office partisons / manufacturers of louvres and blinds etc.	**Additional manufacturing or treatment of powder coated product --> improve product design? Replacement of TGIC-hardener (toxic) in powder coating?**	Interview managing director, WM-facilitator

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Product handling by first, second and third tier clients					
		2-3	*clients level 2:* financial institutions / property developers + building contractors / retailers	**Additional manufacturing or treatment of powder coated product --> improve product design? Replacement of TGIC-hardener (toxic) in powder coating?**	Interview managing director, WM-facilitator
		2-3	*clients level 3:* consumers	**Additional manufacturing or treatment of powder coated product --> improve product design? Replacement of TGIC-hardener (toxic) in powder coating?**	Interview managing director, WM-facilitator

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

NETWORK IMPACT MATRIX

UPDATE: 19 JUNE 2000

NETWORK IMPACT RATINGS FOR: 1M2 POWDER COATED ALUMINIUM

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies					
5,1	material choice for chemicals used used during recycle / waste treatm. process	2	paint waste, including paint dust	Gas is used to heat up the oven to solidy the waste paints which can not be reused in- or externally. Solidy waste paints is done at the same time as curing of new powder coated products and/or during the pre-heating of the oven.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		3	chromium precipitate sludge	Cr6+ is converted to Cr3+ by Na2SO3, addition then lime is added to adjust the pH of the chromate conversion bath.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		2-3?	aluminium precipitate sludge	**Al3+ is precipitated by H2SO4?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		2-3	spent degreasing solutions	Spent degreasing solution is discharged to the sewer at the same time as the spent desmutting solution --> neutralisation. No other treatment of the spent degreasing solution is taking place.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		2-3	spent desmutting solutions	Spent desmutting solution is discharged to the sewer at the same time as the spent degreasing solution --> neutralisation. No other treatment of the spent desmutting solution is taking place.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		4	spent passivation solution	Spent passivation solution is discharged to the sewer every week. The passivation solution contains chromic acid (0.03% v.v.). No treatment of the spent passivation bath is taking place.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		3	spent chromate conversion solution	After the chromium precipitation has settled, the treated chromate conversion solution is discharged to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		3	spent etching solution	After the aluminium precipitation has settled, the treated etching solution is discharged to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		3-4	dirty rinse waters	Dirty rinse water used througout the rinse system is discharged to the sewer without treatment via rinse tank 3 and 4. Rinse water is contaminated with Cr6+ and Cr3+ (4-13 ppm).	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies					
		1-2	domestic waste	Liquid domestic waste (kitchen, toilet, etc) is discharged without treatment to the sewer. Solid domestic waste (office, kitchen) is collected by a commercial waste company / local government to be disposed without treatment on landfill site.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		1-2	industrial waste	Industrial waste is collected by commercial waste company / local government to be disposed without treatment on landfill site.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
5,2	energy use during recycling / waste treatm. process	3-4	paint waste, including paint dust	Paint waste is baked in oven (heated by gas) to solidy. Cyclone is used to rewin the paint dust. Cyclone has efficiency of 90%. Cyclone uses is energy intensive (electricity). **Regular maintenance could improve the efficiency of the cyclone --> one of the waste minisation options.**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		0	chromium precipitate sludge	No or little energy is used to eliminate the Cr6+ and to create the chromium precipitate.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		0	aluminium precipitate sludge	No or little energy is used to precipitate aluminium.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		0	spent degreasing solutions	No or little energy is used to discharge the spent degreasing solution to the sewer..	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		0	spent desmutting solutions	No or little energy is used to discharge the spent desmutiing solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		0	spent passivation solution	No or little energy is used to discharge the spent passivation solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		0	spent chromate conversion solution	No or little energy is used to discharge the spent chromate conversion solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies					
		0	spent etching solution	No or little energy is used to discharge the spent etching solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		0	dirty rinse waters	No or little energy is used to discharge the dirty rinse water to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		2	domestic waste	Transport of solid domestic waste from powder coating company to the landfill site is the only energy intensive process.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		2	industrial waste	Transport of industrial waste from powder coating company to the landfill site is the only energy intensive process.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
5,3	solid residue generated during recycling / waste treatm. process	3	paint waste, including paint dust	Waste paint is reused as much as possible. Some waste powder paint is sold to somebody (who?) who does not require good quality paint. If it is not possible to reuse or sell the waste paint, then it is baked in oven (heated by gas) to solidy for disposal. Frequent colour changes cause mixed colours which has to be disposed --> can not be reused. **Small particles, which are not recovered by cyclone, are emitted to the atmosphere --> should be filtered, but is too expensive.**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		3	chromium precipitate sludge	The chromium precipitate is transferred into drums for collection by commercial waste treatment company to be disposed on landfill site. **Possibility to rewin chrome out of sludge? Treatment of sludge before disposal?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		3	aluminium precipitate sludge	The aluminium precipitate is settled out of the solution and is collected by commercial waste treatment company to be disposed on landfill site. **Possibility to rewin aluminium out of sludge? Treatment of sludge before disposal?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		1	spent degreasing solutions	No or little solid residue is generated for discharging the spent degreasing solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies					
		1	spent desmutting solutions	No or little solid residue is generated for discharging the spent desmutting solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		1	spent passivation solution	No or little solid residue is generated for discharging the spent passivation solution.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		1	spent chromate conversion solution	No or little solid residue is generated for discharging the spent chromate conversion solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		1	spent etching solution	No or little solid residue is generated for discharging the spent etching solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		1	dirty rinse waters	No or little solid residue is generated for discharging the dirty rinse water to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		1-2	domestic waste	Solid domestic waste (office, kitchen) is collected by commercial waste company / local government to be disposed without treatment on landfill site.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		2	industrial waste	Industrial waste is collected by commercial waste company / local government to be dsiposed without treatment on the landfill site.Valuable substances of industrial waste are paper, boxes, plastic. **Is it feasible to collect/dispose paper waste seperately? --> hire container, disposal costs or income? Contamination of bags used to pack solid hazardous chemicals --> are disposed as industrial waste.**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
5,4	liquid residue generated during recycling / waste treatm. process	1	paint waste, including paint dust	No or little liquid residue is generated related to the paint waste and paint dust.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		3?	chromium precipitate sludge	Chromium sludge is dewatered but not 100%. Sludge is disposed by commercial waste treatment company to be disposed on landfill facility. **Can sludge cause leakage on landfill site?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.

environmental concerns	rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies				
	3?	aluminium precipitate sludge	Aluminium sludge is dewatered but not 100%. Sludge is disposed by commercial waste treatment company to be disposed on landfill facility. **Can sludge cause leakage on landfill site?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
	3-4	spent degreasing solutions	Spent degreasing solution is discharged to the sewer at the same time as the spent desmutting solution (once or twice a year) --> neutralisation. No other treatment of the degreasing solution is taking place. **Reuse of spent degreasing bath is possible if oil is filtered out of the solution.**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
	2-3	spent desmutting solutions	Spent desmutting solution is discharged to the sewer at the same time as the spent degreasing solution (once or twice a year) --> neutralisation. No other treatment of the desmutting solution is taking place. Concentration of nitric acid in spent solution is very low (6%).	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
	2-3	spent passivation solution	Spent passivation solution is discharged to the sewer every week on advice of the chemical supplier. The passivation solution contains chromic acid (0.03% v.v.). No treatment of the spent passivation bath is taking place. **External recycle or reuse possible? WM-facilitator is assessing the possibility to change to demineralised water.**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
	3-4	spent chromate conversion solution	After the chromium precipitation has settled, the treated solution is discharged to the sewer --> once a year. **WM-facilitator is assessing the possibility to change to Cr-free of Cr(III) chemicals.**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
	3	spent etching solution	After the aluminium precipitation has settled, the treated etching solution is discharged to the sewer --> once a year. **External recycle or reuse possible?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
	3	dirty rinse waters	Dirty rinse water used througout the rinse system is discharged to the sewer without treatment via rinse tank 3 and 4. Rinse water is contaminated with Cr6+ and Cr3+ (4-13 ppm). **External recycle or reuse possible with ion exchange and closed-loop sytem --> waste minimisation option.**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
	1	domestic waste	Liquid domestic waste (kitchen, toilet, etc) is discharged without treatment to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.

environmental concerns		rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies					
		0	industrial waste	No or little liquid residue is generated by disposing industrial waste on landfill site.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
5,5	gas residue generated during recycling / waste treatm. process	3	paint waste, including paint dust	Paint dust that is not recovered in cyclone (90% efficiency) is discharged to the atmosphere --> **assess feasibility for installation of filter.**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		3?	chromium precipitate sludge	**Toxicity of chromium precipitation?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		2?	aluminium precipitate sludge	**Toxicity of aluminium precipitation?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		0-1	spent degreasing solutions	No or little gaseous residue is generated for the discharging of spent degreasing solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		0-1	spent desmutting solutions	No or little gaseous residue is generated for the discharging of spent desmutting solution to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		2?	spent passivation solution	Chromic acid is included in the USEPA list for air contaminants. **Toxicity of spent passivation solution?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		3?	spent chromate conversion solution	Chromic acid, phosphoric acid, fluorides and calcium hydroxide are included in the USEPA list for air contaminants. **Toxicity of spent chromate conversion solution?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
		2?	spent etching solution	Sodium hydroxide and hydrogen sulfide are included in the USEPA list for air contaminants. **Toxicity of the spent etching solution?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.

environmental concerns	rating*	subcategory	explanation why rating was chosen	reference
Processing wastes of SME by external waste treatment / recycling companies				
	0-1	dirty rinse waters	No or little gaseous residue is generated for the discharging of dirty rinse water to the sewer.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
	0-1	domestic waste	No or little gaseous residue is generated by disposing the domestic waste on a landfill site.	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.
	2?	industrial waste	**Toxicity of contaminants of solid hazardous chemicals in plastic bags?**	Pre-assessment report waste minimisation. Interview managing director, WM-facilitator, UCT supervisor.

* rating from 0 (lowest impact on the environment) to 4 (highest impact on the environment)
To do the rating as objective as possible, consult Appendix D (scoring guidelines and protocols)

Network section:	Contents of worksheet								
1. Shareholders	Material flow (intensity, direction)	Financial flow (intensity, direction)	Information flow (intensity, direction)						Remarks (problems & possibilities past, present, future)
2. Suppliers	~~Location~~	Activity (producer, trading, assembling)	Products supplied (incl. AID / POP)	Material flow (intensity, direction)	Financial flow (intensity, direction)	Information flow (intensity, direction)	~~Rate of importance~~	Transport	Remarks (problems & possibilities past, present, future)
3. Major clients	~~Size of company~~	~~Second tier clients~~	Products purchased	Material flow (intensity, direction)	Financial flw (intensity, direction)	Information flow (intensity, direction)	~~% revenue generated by client~~	Transport	Remarks (problems & possibilities past, present, future)
4. Major competitors	~~Location~~	Products manufactured	Competition region / market	~~Competition to company~~	~~Strengths / weaknesses of competitor~~	Information flow (intensity, direction)	Influence competitor		Remarks (problems & possibilities past, present, future)
5. Utility providing organisations (electricity + water)	Material flow (intensity, direction)	Financial flow (intensity, direction)	Information flow (intensity, direction)	~~Implemented saving techniques~~					Remarks (problems & possibilities past, present, future)
6. Waste treatment and recycling organisations	Waste stream	Waste treatment / recycling organisation	Material flow (intensity, direction)	Financial flow (intensity, direction)	Information flow (intensity, direction)	~~Waste treatment process~~		*Transport*	Remarks (problems & possibilities past, present, future)
7. Support organisations	Purpose of association	Material flow (intensity, direction)	Financial flow (intensity, direction)	Information flow (intensity, direction)					Remarks (problems & possibilities past, present, future)
8. Government & community organisations	Purpose of association	Material flow (intensity, direction)	Financial flow (intensity, direction)	Information flow (intensity, direction)					Remarks (problems & possibilities past, present, future)
9. Maintenance	Kind of maintenance	Material flow (intensity, direction)	Financial flow (intensity, direction)	Information flow (intensity, direction)					Remarks (problems & possibilities past, present, future)

XXXX = suggested to add to contents of the worksheet
~~XXXX~~ = suggested to eliminate from the contents of the worksheet